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Francis G. Pease
1881-1938

By GUSTAF STRÖMBERG

On February 7, 1938, in Pasadena, the earthly life of Francis G. Pease came to an end. To his fellow voyagers on the ocean of life he held a cherished position as a man, a friend, and an astronomer.

Dr. Pease was born in Cambridge, Massachusetts, in 1881, but his parents soon moved to Highland Park, Illinois, where his father was a business man and Justice of the Peace. One of a family of five children, he inherited sturdy qualities rather than wealth; in particular, a sense of independence and self-reliance with regard to both material and spiritual things. His mother, of whom he often spoke in later years, taught her children to think and act independently and to form their own opinions about life and its problems. Having attended High School in Highland Park, Pease studied at the Armour Institute of Technology in Chicago, where he graduated in 1901 and later received the honorary degrees of M.A. and Sc.D.

During his stay in Chicago he worked in the evenings at the optical shop of Petitdidier, and there he learned the practical side of instrument making and design. Petitdidier, in turn, recommended his young apprentice to George W. Ritchey who needed assistance in his optical work at the Yerkes Observatory. In 1901 Pease went to the Yerkes Observatory and began the routine work of grinding lenses and mirrors. Shortly afterwards he began to take part in astronomical observation, and was thus started on his career as an engineer and astronomer.

In 1904 he met at the Yerkes Observatory Miss Caroline T. Furness of Chicago, whom he married in 1905. With Messrs. Hale, Ritchey, Adams, and Ellerman he went to Pasadena in 1904 and took part in the early work of the Mount Wilson Observatory. Apart from the year 1918, when he was chief draftsman in the engineering section of the National Research Council, he was connected with the Mount Wilson Observatory until his death.

Together with Mr. Ritchey he designed most of the early equipment of the Mount Wilson Observatory. The details of the plans of the 100-inch telescope were largely his own, and he supervised the construction of this large instrument which for 20 years has been used so successfully in pushing out the frontiers of the known universe. The 50-foot interferometer was also designed by him, as well as most of the smaller instruments at the Mount Wilson Observatory.

His astronomical work consisted mainly in direct photography,

studies of clusters and nebulae, and in the determination of the diameters of stars by use of the interferometer. He made the first determinations of the rotation of extra-galactic nebulae by use of the spectrograph. He was a member of the Committee for Study of the Surface Features of the Moon appointed by the President of the Carnegie Institution, and he obtained a number of photographs of the moon for this committee. He made the first direct measurement of a stellar diameter with the use of a 20-foot interferometer attached to the 100-inch telescope in the year 1920. This work was later continued with the 50-foot interferometer, with which he was able to measure the diameter of several bright stars.

The interferometer work was done on the initiative of Dr. A. A. Michelson, and this started a cooperative work which continued till Michelson's death in 1931. Pease prepared the instrumental equipment used on Mount Wilson and Mount San Antonio for the determination of the velocity of light in the years 1924-1928. In 1930 when work was started on the project to measure the velocity of light in a mile-long evacuated pipe placed at Irvine Ranch near Santa Ana, California, most of the responsibility fell on Pease. After Michelson's death he and Mr. Fred Pearson of the Ryerson Laboratory continued the observations and finished the work in 1934. In 1929 Pease repeated the Michelson-Morley ether drift experiment, using a path 85 feet long, and confirmed the negative result previously obtained. All of these investigations were of a fundamental character and were carried out with instrumental equipment of extraordinary ingenuity and perfection. The observations themselves involved the highest precision known to physical technique and required vast patience and perseverance on the part of the observer.

Following his work in connection with the design of the 100-inch telescope, Pease became much interested in the construction of very large telescopes and in 1926 he elaborated a tentative design for a 300-inch telescope and thoroughly discussed the difficulties to be encountered in such an undertaking. He advocated the fork type of mounting and proposed the use of Pyrex glass for the mirror. Later, through the efforts of Dr. Hale, funds were obtained from the Rockefeller General Education Board for the construction of a 200-inch telescope. Work on this instrument was started in 1930, and Pease from that time on spent about half his time in the work of planning and designing this large telescope, which is now approaching completion.

Pease's training was along practical lines and his work was largely limited to the practical aspects of observing, measuring, and designing. But he was interested in many fields of astronomy and physics, and he loved to discuss with his associates the future development of these sciences, the fundamental problems in research, and the theoretical and practical value of increased knowledge to mankind.

We should, however, not judge a man solely by his professional ac-

complishments which may often be the result of circumstances and opportunities. In addition to his distinguished achievement in engineering and astronomical fields, Pease was personally a man of fine character, who made great sacrifices for those he loved. Optimism and perseverance were his outstanding characteristics. No task within his field was too difficult for him to undertake and he was not discouraged by failure or lack of recognition. He had, so far as I know, no enemies, but many friends. He was always considerate in his contact with other men. His memory will always shine as a kindly light in the unfathomable depths of Cosmos.

MT. WILSON OBSERVATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON,
MAY 23, 1938.

Astronomical Symposium

By J. J. NASSAU

On the seventh and eighth of May, 1938, a group of astronomers and physicists met at Hudson, Ohio, to commemorate the centennial of the founding of the Loomis Observatory, one of the two oldest observatories in the United States. The Hopkins Observatory at Williams College, founded in the same year, celebrated its centennial last autumn.

The Neighborhood Group of Ohio Astronomers, together with the Ohio Academy of Science, formed the nucleus of the gathering. Many astronomers and physicists from neighboring states and the Province of Ontario also attended the meeting. All were guests of Western Reserve Academy. Our hosts most generously entertained us on their attractive campus, providing meals, lodging, teas, and many other courtesies. The local committee, under the able chairmanship of Mr. R. H. Cleminshaw of the Academy teaching staff, perfomed its task most admirably.

At 2:30 P.M. on Saturday just before the symposium, Dr. Joel B. Hayden, headmaster, in a short address welcomed the visiting scientists. Dr. Dean B. McLaughlin, Dr. Otto Struve, and Dr. Donald H. Menzel presented the papers of the symposium and were the principal participants in the subsequent discussions.

In the evening some five hundred people were served at dinner in Cutler Hall. Those attending included the students, alumni, and trustees of the Academy, and the visiting scientists.

Dr. Harlow Shapley with his characteristic enthusiasm and fine humor gave the principal address of the evening, on "Sidereal Organizations." It included a discussion of recent researches on the extension of the southern extra-galactic survey, the "galactic windows," and a description of the new supposed extra-galactic globular cluster. Later, Dr. H. D. Curtis kindly presented a double showing of the recent solar movies made at the McMath-Hulbert Observatory of the University of Michigan.

The Loomis Observatory with its original instruments—the 4-inch equatorial with its unique observing platform, and the 3-inch transit circle—was open for inspection. Many scientists visited also the laboratory of Edward W. Morley, who was professor of chemistry at Western Reserve College and who taught in Hudson before this institution was moved to Cleveland.

DISTINGUISHED GUESTS AT WESTERN RESERVE ACADEMY'S CENTENNIAL CELEBRATION OF LOOMIS OBSERVATORY

Left to right: front row, Dr. Joel B. Hayden, academy headmaster; Dr. Harlow Shapley, Harvard College Observatory; Dr. D. B. McLaughlin, University of Michigan; Dr. W. I. Milham, Williams College; Dr. J. J. Nassau, Case School of Applied Science; back row, Dr. H. W. Montcastle, Western Reserve University; Dr. S. W. McCuskey, Case School of Applied Science; Dr. D. H. Menzel, Harvard College Observatory; Dr. Otto Struve, Yerkes Observatory.

The Sunday morning session was held in the fine colonial chapel built in 1836. Dr. Joel B. Hayden conducted the service. Dr. Willis I. Milham of Williams College and Professor H. W. Mountcastle of Western Reserve University gave short addresses, bringing felicitations from their respective institutions. The principal address was made by Professor Dayton C. Miller of Case School of Applied Science, who spoke on "The Service of Science in the World Today."

The scientific proceedings of the afternoon meeting will be published in a commemorative booklet, which will be distributed to participants in the celebration and to other astronomers. It will include the symposium addresses and a short historical sketch, as follows:

"Some Problems of Peculiar Stellar Spectra," by Dr. Dean B. McLaughlin.

"The Observation and Interpretation of Stellar Absorption Lines," by Dr. Otto Struve.

"Theoretical Problems of Stellar Absorption Lines," by Dr. Donald H. Menzel.

"Astronomy in the Early Days of the Western Reserve," by Mr. R. H. Cleminshaw of Western Reserve Academy.

Dr. McLaughlin's contribution appears in the present number of POPULAR ASTRONOMY. Others will follow in succeeding numbers.

WARNER AND SWASEY OBSERVATORY, CASE SCHOOL OF APPLIED SCIENCE.
MAY 19, 1938.

Some Problems of Peculiar Stellar Spectra

By DEAN B. McLAUGHLIN

The subject of peculiar stellar spectra is so large and so complex that it is necessary to limit the field at the outset. There would be ample precedent for including in this discussion almost anything bearing on the spectra of stars other than those which are thoroughly typical of the Draper classes. In the older lists of peculiar spectra[1] we find even such typical objects as stars of classes R, N, S, Oe5, double-lined spectroscopic binaries, Algol variables, composite spectra, and gaseous nebulae. The composite spectra are perhaps allowable, as some of them have turned out to belong to single abnormal stars rather than to the two components of a double. But the rest of the preceding types have no place in a modern list of objects with peculiar spectra.

Almost all intrinsically variable stars have spectra which are in some measure peculiar. The Cepheids exhibit variations of spectral class, associated with changes of photospheric temperature. The long-period variables have spectra which are more peculiar, in that they possess bright lines of hydrogen and other elements. The origin of the hydrogen emission lines is an enigma, but there is perhaps some comfort in the thought that we can account for the variations of their absorption spectra and their changes of magnitude in terms of varying temperature, with associated changes of TiO absorption. The c-stars may still be admitted to the peculiar category, although we now recognize that they present only an exaggeration of the well-known absolute magnitude effect. Some new types of peculiar spectra have been recognized in recent years, as a result of the more intensive study of the brighter stars and the extension of observations to fainter ones.

The objects now allowable in a tabulation of peculiar spectra fall into seven main groups, though there are a few stars which appear to require separate mention. The groups are:

[1] *Harvard Annals* **28** and **56**.

1. The c-stars, including some with so-called composite spectra.
2. Morgan's Manganese-Europium-Chromium-Strontium sequence, including the α Canum Venaticorum spectrum variables.
3. Cepheid, long-period, and RV Tauri variables, and related objects.
4. Normal stars of class Be.
5. Peculiar Be stars and miscellaneous peculiar bright-line objects.
6. The Wolf-Rayet stars.
7. The novae, and nova-like stars.

For various reasons the first three groups will not be considered at length, though some of their characteristics correlate with those of the more peculiar objects and will therefore be noticed as occasion requires. The Wolf-Rayet stars will be omitted because their problem is so close to that of the novae. The field thus narrows down to the normal and peculiar Be stars and the novae.

The Stars of Class Be

The spectra of Be stars differ considerably from one another, but certain characteristics are common to most members of the class. The Hα emission line is invariably the strongest, and the intensities decrease with wave-length in the Balmer series; there is no intensity anomaly like that found in the long-period variables of class Me. In a number of spectra having rather strong hydrogen emission we find also a number of bright lines of Fe_{II} and a few due to other metals. Helium emission occurs only rarely. The bright lines of hydrogen are almost always superimposed upon diffuse absorption, and other dark lines, notably those of helium, are usually fuzzy and difficult to measure. The emission lines are of different width (from one to ten angstroms) in different stars, but in any given spectrum the widths are proportional to the wave-length. In those spectra having emission of large or moderate width (three angstroms or more) there are rather narrow absorption lines superimposed centrally on the emission. In some spectra these lines are rather weak, so that they could be interpreted as mere spaces between two bright components. In others, however, they are strong and sharp, leaving no doubt that they actually represent absorption of the central parts of the wider bright lines. In some spectra of class Be which have such sharp strong central absorption there are numerous sharp enhanced metallic absorption lines. These spectra have often been called composite, but it is now quite certain that only one star is involved.

An important characteristic of spectra of class Be is their tendency to vary. The Michigan program of observation has included 42 of these objects over intervals of eight to 27 years. Of this number, thirty have shown definite spectral changes of some kind, and a few others are suspected. Evidently variability is the rule and constancy the exception.[2]

The spectral changes can be grouped under three headings, but they are not mutually exclusive. So far as we may judge from so few cases,

[2] *Mich. Obs. Publ.*, **4**, 193, 1932; *Aph. J.*, **85**, 181, 1937.

the number of combinations of types does not differ significantly from the number to be expected according to chance. The types are:

1. The E/C variables. The emission lines show changes of total intensity relative to the continuous spectrum.

2. The V/R variables. Many stars having double emission (a broad bright line divided by absorption) show changes of the relative intensity of the two emission components.

3. Metallic absorption variables. These stars have sharp central absorption lines of hydrogen and faint sharp absorption lines of ionized metals. The latter vary from conspicuousness to invisibility.

The E/C Variables

The first type of variation need not detain us long. Examples of it are 11 Camelopardalis, 31 Pegasi, and β Piscium. The emission lines change together in a long period. The shortest known cycle is ten years, and some stars which lost their bright lines many years ago have not yet recovered them (e.g., Pleione). The loss is probably not permanent, for the lines have reappeared in several stars. The changes are irregular and unpredictable, but are usually slow. No conspicuous variations of radial velocity are associated with the changes of emission in any of these stars examined to date. When the bright lines are gone the underlying spectrum which is revealed is a normal one of class B with diffuse lines, and there is no known way of distinguishing an ex-emission star from one which never had bright lines. Spectra of β Piscium at times when the emission lines were strong and weak are shown in Plate III.

The V/R Variables

Variations of the type V/R are much more complex and intriguing. These changes are usually cyclic in character, and in most spectra the oscillation is symmetrical about equality. Stars in which only one component varies or in which one is always the stronger are uncommon.

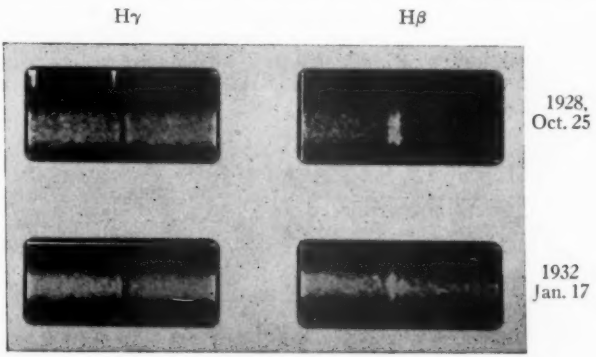


Figure 1.
β^1 Monocerotis

With one exception the periods are a few years in length; the longest known is about eleven years. Like the E/C variables, these stars are irregular in their changes. Recorded extremes in one case (25 Orionis) show the longest cycle twice as long as the shortest. Except for superimposed and independent variations of E/C, the total intensities of the emission lines do not change during the V/R cycle; what one component gains in strength the other loses. In Figure 1 portions of the spectrum of β^1 Monocerotis are reproduced, showing extremes of the variation of Hβ and Hγ.

Marked changes of apparent radial velocity of the emission and its central absorption accompany the variation of V/R. When the violet component is the stronger the central absorption and the whole emission are both shifted towards greater wave-length, and opposite displacements occur when the red component is the stronger. Ranges of velocity are of the order of 50 to 100 km/sec. We get quite similar curves if we plot against the time any one of three quantities: (1) the intensity ratio V/R of the emission components; (2) the velocity of the central absorption of hydrogen; (3) the velocity of the hydrogen emission (based on the mean of the extreme edges or the mean of the centers of the two components). Such curves for π Aquarii are shown in Figure 2. Early

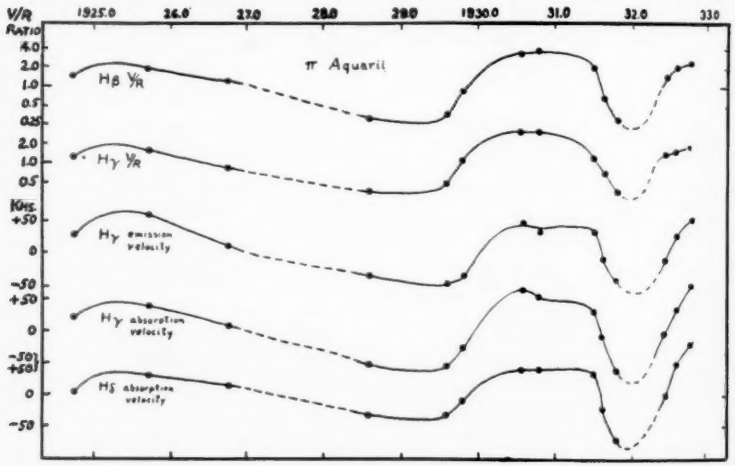


FIGURE 2.

CURVES FOR π AQUARII

V/R for Hβ and Hγ, emission velocity of Hγ, absorption velocity of Hγ and Hδ.

superficial observations led some investigators to believe that the shifting of the central absorption was merely a consequence of crowding by the stronger emission component. The bodily shift of the emission in the *same* direction as its central absorption completely explodes this idea.

We may rest assured that the apparent velocities constitute a real phenomenon of the star's atmosphere, and not a spurious effect originating in the photographic emulsion.

Another variation, concurrent with those just discussed, was found a few years ago. The wings of the diffuse underlying absorption vary in strength approximately with the neighboring component of the emission. This is tentatively referred to the displacement of the emission which uncovers a deeper part of the absorption contour.* The variations are summarized in the schematic contours shown in Figure 3.

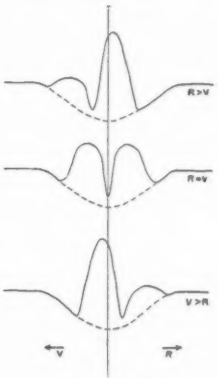


FIGURE 3.
SCHEMATIC CONTOURS OF HYDROGEN LINES OF A V/R VARIABLE

More accurate study shows small differences of phase between the several curves. The absorption velocities are all in phase, as are the emission velocities, but in 25 Orionis Miss Dodson[3] found a distinct lag of phase of the absorption relative to the emission, amounting to 100 days in the period of 1800 days. The curves of V/R for different lines disagree systematically; the higher members of the Balmer series anticipate the lower. On some plates of γ Cassiopeiae the red component of Hγ was much the stronger, while the ultra-violet Balmer lines had their violet components more intense. The same phenomenon has been found in β^1 Monocerotis, 25 Orionis, and π Aquarii. The manner of correlation of these curves, and their systematic differences, undoubtedly have some important physical significance. The interpretation is likely to be complex, as it must be bound up with the conditions of origin of three different features: the broad underlying absorption, the emission, and the superimposed central absorption.

*Probably some other effect is involved in addition to the shift of the emission, as Miss Dodson has shown that the variation of the absorption borders in 25 Orionis is a little out of phase with the changes of V/R of the emission.

[3] *Aph. J.*, **84**, 180, 1936.

Measures of the velocity of the underlying broad absorption lines of hydrogen are next to impossible. By measuring contours on microphotometer tracings, Miss Dodson obtained indications of oscillation opposite to that of the emission and central absorption, though the range was small enough and the scatter of the measures sufficiently great to render the apparent changes of position inconclusive. However, the idea that the underlying absorption might shift with the central absorption finds a definite negation in these observations. The diffuse helium lines were studied in a similar fashion and appeared to confirm the curves given by the diffuse hydrogen. These data are entitled to greater weight because there is no known emission to vitiate the measures of the helium lines. This aspect of the problem is in need of further investigation, particularly in other stars. Higher dispersion might help in improving the accuracy of the contours, but under conditions existing at Ann Arbor a larger telescope would be needed to keep exposure times within reasonable limits.

Interpretation of the V/R Variations

It is not possible to give here a comprehensive treatment of the hypotheses devised to account for V/R variation; only a general outline will be presented. It was shown by Struve[4] that the emission stars generally have diffuse absorption lines and that the width of the emission is positively correlated with that of the absorption. Consequently he inferred that the broadening of both was due to rotation. This interpretation was strongly suggested by the proportionality between width and wavelength of the emission lines, which is most readily explained as a Doppler effect. Struve assigned the broad underlying absorption to the reversing layer of a rapidly rotating star and the hydrogen emission to a rotating ring or shell of gas. If we postulate a sufficient thickness of the external shell, this hypothesis gives a good account of the appearance of a non-variable Be spectrum with central absorption. Only a year or so earlier, Beals[5] had proposed an expanding atmosphere, analogous to that of a nova, to account for the emission bands of Wolf-Rayet stars and for the structure of the absorption and emission lines of P Cygni.

The hypotheses of Struve and Beals were combined by the author[6] in an attempt to explain the variations of V/R and the accompanying changes of velocity. A rotating atmosphere which alternately expanded and contracted was found to give a good qualitative account of both. The emission is supposed to originate in the inner portions of the extensive chromosphere and the absorption mainly in the outer layers. During expansion the light from the receding gas on the far side of the star and at the receding limb would pass freely through the approaching gases in the atmosphere nearer the observer, since the Doppler effect of their

[4] *Aph. J.*, **73**, 94, 1931.
[5] *Dom. Astroph. Obs. Publ.*, **4**, 288, 1930.
[6] *Publ. Amer. Astr. Soc.*, **7**, 31, 1931; *Proc. Nat. Acad. Sci.*, **19**, 44, 1933.

relative velocities renders absorption impossible. On the other hand, light coming from the approaching gases of the inner atmosphere nearer the observer must pass through gases of the outer layers which are also approaching, and much of it would be absorbed. Therefore the red component of the emission would be strong and the violet weak. Thus,

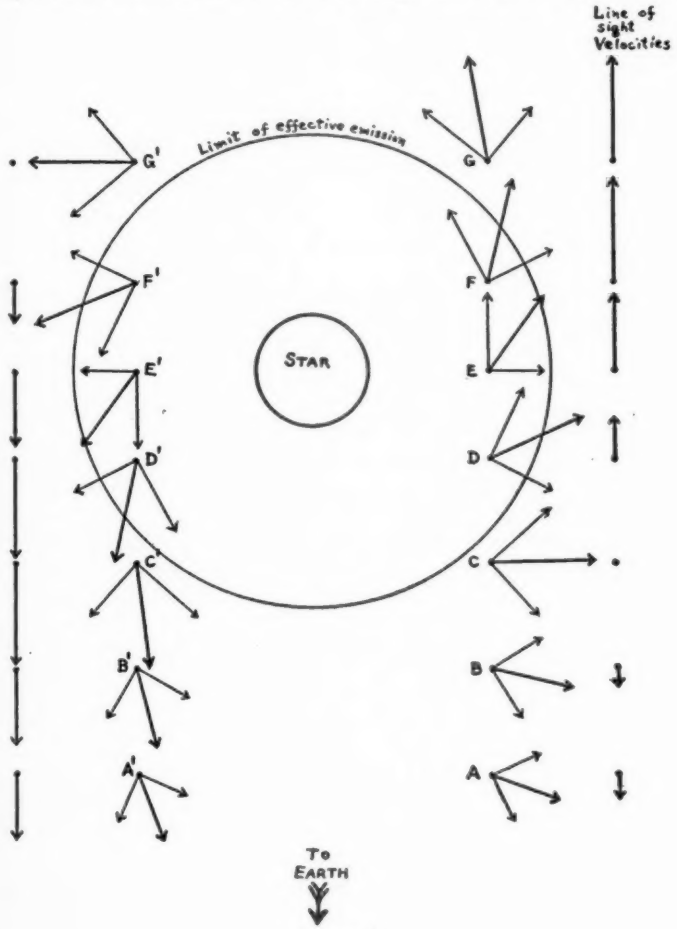


FIGURE 4.

ROTATING-PULSATING MODEL OF A Be ATMOSPHERE IN THE EXPANDING STAGE

in Figure 4, the atoms at A, B, and C are incapable of absorbing the light emitted by D, E, and F, because their line-of-sight velocities

(shown at the edge of the figure) are very different. But light emitted by D′, E′, and F′ would suffer a large loss from absorption by the atoms at A′, B′, and C′, since all have velocities of approach of the same order of magnitude. It can easily be seen that collapse of the atmosphere would lead to an opposite inequality. Further, the gases between the observer and the star would produce the central absorption shifted towards the violet during expansion and towards the red during collapse, and some of the gases on the far side would be occulted by the star, which would result in an apparent displacement of the edge of the emission line. This would be most effective on the low-level lines, and possibly negligible for those originating in the largest shell. It is not to be supposed that the absorbing and emitting shells experience any such change of size as the velocities and their duration would appear to indicate. The Doppler effects are regarded as due to the motions of individual atoms *streaming through* the regions within which the effective emission and absorption originate.

Soon afterward Gerasimovic[7] showed that centrifugal acceleration due to rotation would assist radiation pressure in ejecting atoms from the hotter stars, thus accounting for the association of emission lines with diffuse absorption spectra. He proposed a different hypothesis of the V/R variation. The essential difference lies in the absence of any collapsing stage; instead, one ejected shell continues to expand while a new one forms. When a shell has reached a considerable thickness, the radiation (in Lyman α) which it sends back to the photosphere prevents the ejection of more atoms until the shell has expanded a sufficient distance to weaken the back radiation. This is a particularly attractive idea, since the mechanism works automatically. It gives a qualitative account of the variations of the emission lines, but the writer is unable to reconcile it readily with the variations of velocity of the central absorption. The velocity curves fail to show the discontinuities and the systematically negative values which this hypothesis appears to require.

Whatever may be the correct interpretation of the variations, the manner of origin of the bright lines seems to be clearly indicated. Mohler's[8] measurements of emission intensities and his calculations of the temperatures of the stars fully support the hypothesis that the emission lines originate in recombination of hydrogen atoms which were photoelectrically ionized by continuous stellar radiation beyond the Lyman limit.

Extraordinary good luck has also given us an approximate measurement of the actual extent of the emission atmosphere of a Be star. The disappearance of the hydrogen emission and the long violet extension of the spectrum of VV Cephei led the writer to suggest[9] that the system

[7] *M. N.*, **94**, 737, 1934; *Obs.*, **58**, 115, 1935.
[8] *Mich. Obs. Publ.*, **5**, 43, 1933.
[9] *Harv. Ann. Card*, 397, 1936.

was an eclipsing binary. This was fully confirmed by Gaposchkin's[10] determination of the light curve and of the spectrographic orbit of the M-type star. The duration of the phases of disappearance and reappearance of the hydrogen emission lines gives the approximate dimensions of the emitting shells. Goedicke[11] has calculated conservatively that the Hβ shell is about as large as Antares, and the Hγ shell about half as large. The size of the B-type star is not accurately determined, but it can hardly be more than one-fifteenth as large as its Hβ atmosphere.

Until a short time ago it was thought that the V/R variables continued their activity indefinitely and that other stars remained always with their emission components equal. The beginning of activity in the spectrum of γ Cassiopeiae directed attention to other cases, and it was found that within the interval 1911 to 1936 the stars π Aquarii, β^1 Monocerotis, and γ Cassiopeiae changed from constancy to variation of the V/R type, while ζ Tauri, b^2 Cygni, and 25 Orionis ceased their V/R variations. These spectrum variables therefore present a problem whose solution will require observations over many decades. It appears probable that most Be stars alternate between constancy and variability.[12]

Before leaving the V/R variables we should note a possible extension of the writer's hypothesis of their mechanism to the long-period variables of class Me. Like the Be stars, they may be regarded as having hydrogen atmospheres of very great extent. If we also admit that TiO extends rather high above the effective photosphere we can explain qualitatively some of the anomalies of their spectra. In o Ceti the maximum of absorption velocity occurs at maximum of light, and the hydrogen emission lines are strongly displaced to the violet with respect to the absorption spectrum. This can be explained in the following manner. During the most rapid inrush of the gases the emission due to hydrogen on the far side of the atmosphere will be shifted from its normal frequency and will not be absorbed by hydrogen on the near side. The emission lines, negatively displaced, will shine through strongly. The metallic absorption lines, which originate on the nearer side of the star, will be shifted towards greater wave-lengths. Both displacements arise from the same cause, but they are opposite because the lines originate on opposite sides of the star. It is not necessary to postulate an extent of TiO *above* the hydrogen emitting layers; we need only suppose that it extends nearly as far from the photosphere as does hydrogen. Since the emission comes chiefly from the far side of the atmosphere, the molecules of TiO on the near side absorb it, thus accounting for the intensity anomalies.

[10] *Harv. Circ.*, 421, 1937.
[11] *Publ. Amer. Astr. Soc.*, **9**, 122, 1938.
[12] *Aph. J.*, **85**, 181, 1937.

The "Composite" Be Spectra

A number of Be stars show spectra which have been called "composite." These have diffuse lines of He_I and Mg_{II} and diffuse underlying hydrogen absorption. The hydrogen emission is usually bisected by a very narrow and strong absorption line. Throughout the spectrum there appear sharp enhanced metallic absorption lines. Their pattern usually matches fairly well the spectrum of the c-star α Cygni. In this group we find such stars as ϵ Capricorni, ζ Tauri, HD 45910, HD 217050, and o Aquarii. We also note υ Sagittarii as a case too extreme to be typical.

Most of the spectra in this group are variable. In 1914 the spectrum of ζ Tauri (Plate III) contained rather strong sharp metallic lines, but before 1921 they faded considerably, and they are now difficult to see. Cyclic changes of intensity of the metallic lines occur in ϵ Capricorni and HD 45910.[13] The cycle of HD 217050 is many years in length; between 1921 and 1928 the metallic lines and sharp hydrogen absorption appeared, and the spectrum has remained unchanged to the present time. (Plate IV).

These semi-periodic changes suggest the formation and dissipation of a high-level shell of absorbing gas. In at least one case, HD 217050, the metallic and hydrogen absorption developed together. This concurrent change, and the sharpness of the lines in contrast to the diffuse underlying spectrum, suggest that the hydrogen and metallic absorption originate in approximately the same region. The extreme sharpness of the hydrogen lines indicates a very tenuous atmosphere without any considerable velocity of rotation. All these considerations point to a shell of gas far above the photosphere. Recently γ Cassiopeiae (Plate IV) has given a demonstration of this type of change. In its normal state the spectrum was one of class B with very diffuse absorption and strong emission with faint central absorption. During a stage in which the red emission component was the stronger (atmospheric expansion) strong sharp central absorption developed at the lines of hydrogen and helium. Only feeble traces of the Fe_{II} absorption lines appeared. Here again all the sharp absorption features developed together. The fact that helium appeared instead of iron seems to be a question of excitation rather than an inconsistency.

Several stars other than those of class Be exhibit phenomena which appear to require shells of gas distant from the star. One which still appears unique is 17 Leporis which Struve[14] has shown to possess an apparently composite variable spectrum. Diffuse hydrogen and Mg_{II} lines are accompanied by variable sharp enhanced metallic lines which appear and disappear, varying over a range of about 100 km/sec. The diffuse spectrum is referred to the reversing layer of a rotating star,

[13] Plaskett, *Dom. Astroph. Obs. Publ.*, **4**, 18, 1926.

[14] *Aph. J.*, **76**, 85, 1932.

while the sharp lines are considered to originate in a series of ejected shells. A similar but non-variable association of diffuse and sharp spectra was found by Morgan[15] in 14 Comae.

Passing to more nearly normal spectra, we note that Adams and McCormick[16] found systematic shifts and asymmetries of lines of Na_I and Ca_{II} in several supergiant stars. The displacements are towards the violet, indicating atmospheric expansion. Recently Spitzer[17] has found some ultimate lines in class M supergiants to consist of two parts, a wide line with a sharp one superimposed and shifted towards the violet an amount equivalent to 10 km/sec. The conspicuous phenomena shown by the "composite" Be spectra and that of 17 Leporis are probably only an exaggeration of a rather common characteristic of supergiant stars with extensive atmospheres.

Miscellaneous Peculiar Spectra

Effects apparently closely related to those just described, but associated with stars of various types, deserve mention at this point. In the spectrum of HD 190073 Merrill[18] found very diffuse hydrogen absorption with narrow central emission. The lines of Ca_{II} are shifted about 3 A towards the violet. The analogy with novae is evident, but the star is not variable and no other lines show the effect. In the spectrum of HD 31293 Merrill[19] found sharp absorption which oscillated from an undisplaced position to one considerably shifted to the violet, while underlying diffuse absorption remained approximately fixed. Sharp absorption superimposed on a very fuzzy line has been found by O. C. Wilson[20] in the spectrum of θ^2 Orionis. In this case, however, only $H\zeta$ shows the effect and the position of the line shows it to be due to absorption by helium in the Orion nebula. The circumstance that the lower level in this transition is metastable makes possible a sufficient population in that state to permit detection of the line.

The star XX Ophiuchi[21] carries the formation of an outer absorbing stratum to an extreme. First announced as an "iron star" because its spectrum consisted chiefly of bright iron and hydrogen lines, this object passed through a complete cycle of changes in several years. The emission faded and a stronger continuous spectrum emerged, with very intense absorption lines of Fe_{II} and Ti_{II}, while the hydrogen lines developed P Cygni structure. Then the spectrum slowly reverted to its bright-line character. The most remarkable part of the story is that, although the star is variable, almost all the striking changes occurred during constant maximum light. The variations are quite similar to

[15] *Aph. J.*, **76**, 144, 1932.
[16] *Publ. Amer. Astr. Soc.*, **8**, 106, 1935.
[17] *Publ. Amer. Astr. Soc.*, **9**, 134, 1938.
[18] *Aph. J.*, **77**, 51, 1933.
[19] *Aph. J.*, **77**, 103, 1933.
[20] *Publ. A. S. P.*, **49**, 338, 1937.
[21] Merrill, *Aph. J.*, **75**, 133, 1932.

those of R Coronae, but in that case the bright-line phase occurs only during minimum, and the dark-line spectrum at maximum. Conjecturally we may refer these changes to the formation of an outer shell of gas which is not only an absorbing atmosphere but is thick enough to be opaque to continuous radiation,—a sort of false photosphere which occasionally clears away. There is a close analogy with novae; a similar mechanism has been suggested to account for the deep minimum of Nova Herculis.[22]

In many of the peculiar cases discussed above we have brought in again and again the idea of extensive atmospheres detached from the stars. The astronomical mind is better prepared to believe in such structures now than it was ten years ago. Those who have worked with peculiar spectra have long been believers in very extensive and tenuous atmospheres, but observational proof was required. Fortunately we have had such proofs in astonishingly rapid succession: ϵ Aurigae, ζ Aurigae, and now VV Cephei which is composed of a giant M star with an atmosphere as thick as its own radius, and a B-type companion having a hydrogen emission envelope as large as Antares. In the stages before or after an eclipse of ζ Aurigae or VV Cephei the effects of absorption of light of the early-type star by the atmosphere of the red component resemble in a general way the "composite" spectra of some Be stars, and the writer[23] has pointed out a similarity to the later stages of the principal absorption spectrum of Nova Herculis. All these phenomena are considered as having a similar origin: absorption of the light of a hot star by a very tenuous stratum of gas far from the photosphere.

The Cor Caroli Variables

The appearance and disappearance of absorption lines leads us to consider another type of spectrum variable, which is exemplified by α Canum Venaticorum. Several stars are now known[24] to show similar cyclic changes of intensity of the absorption lines of one or two elements only. The effects are somewhat contradictory in the several stars. Thus:

49 Cancri	Eu_{II} and Sr_{II} vary oppositely
ω Ophiuchi	Sr_{II} varies
73 Draconis	Eu_{II} and Ti_{II} vary together
γ Equulei	Cr_{II} varies
BD $-18°3789$	Eu_{II} and Cr_{II} vary oppositely
α Canum Ven.	Eu_{II} varies

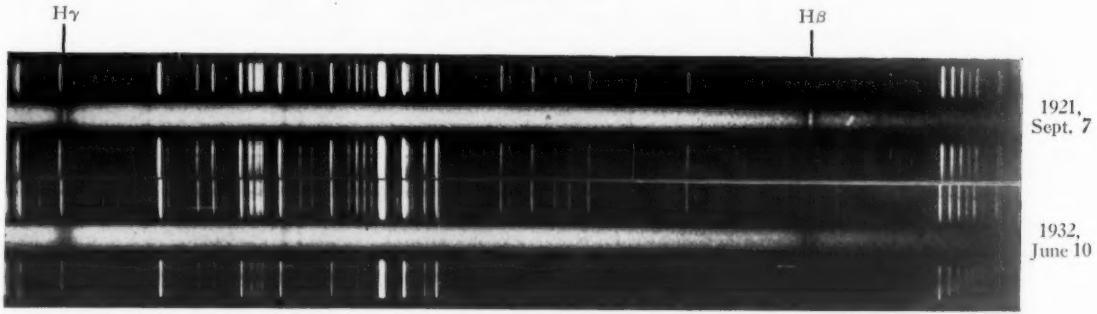
There is not much system about these except the limitation of the variable lines to Eu_{II}, Sr_{II}, and Cr_{II} (with Ti_{II} in one star only). To complicate matters, the statistics of europium stars show that strong Eu_{II} lines are *associated with* strong Cr_{II}, in spite of their *opposite variations* in one star. We may refer the peculiarities of constant spectra to differ-

[22] McLaughlin, *Mich. Obs. Publ.*, **6**, 212, 1937; Grotrian, *Zs. f. Aph.*, **13**, 215, 1937.

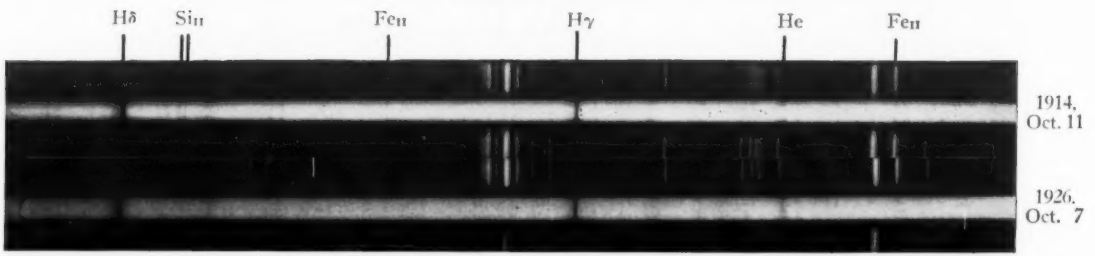
[23] *Mich. Obs. Publ.*, **6**, 149, 1937.

[24] Morgan, *Aph. J.*, **76**, 315, 1932.

PLATE III

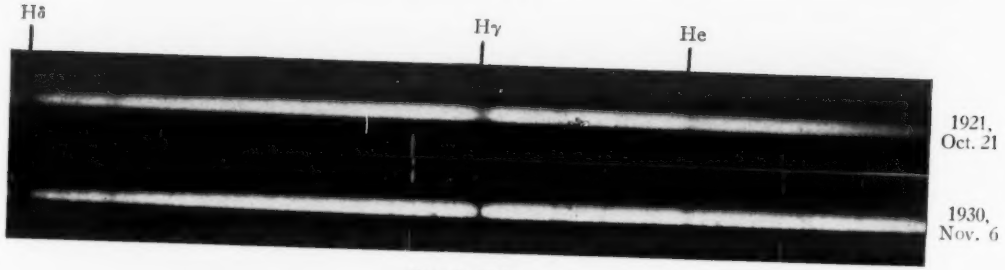


β Piscium



ζ Tauri

PLATE IV

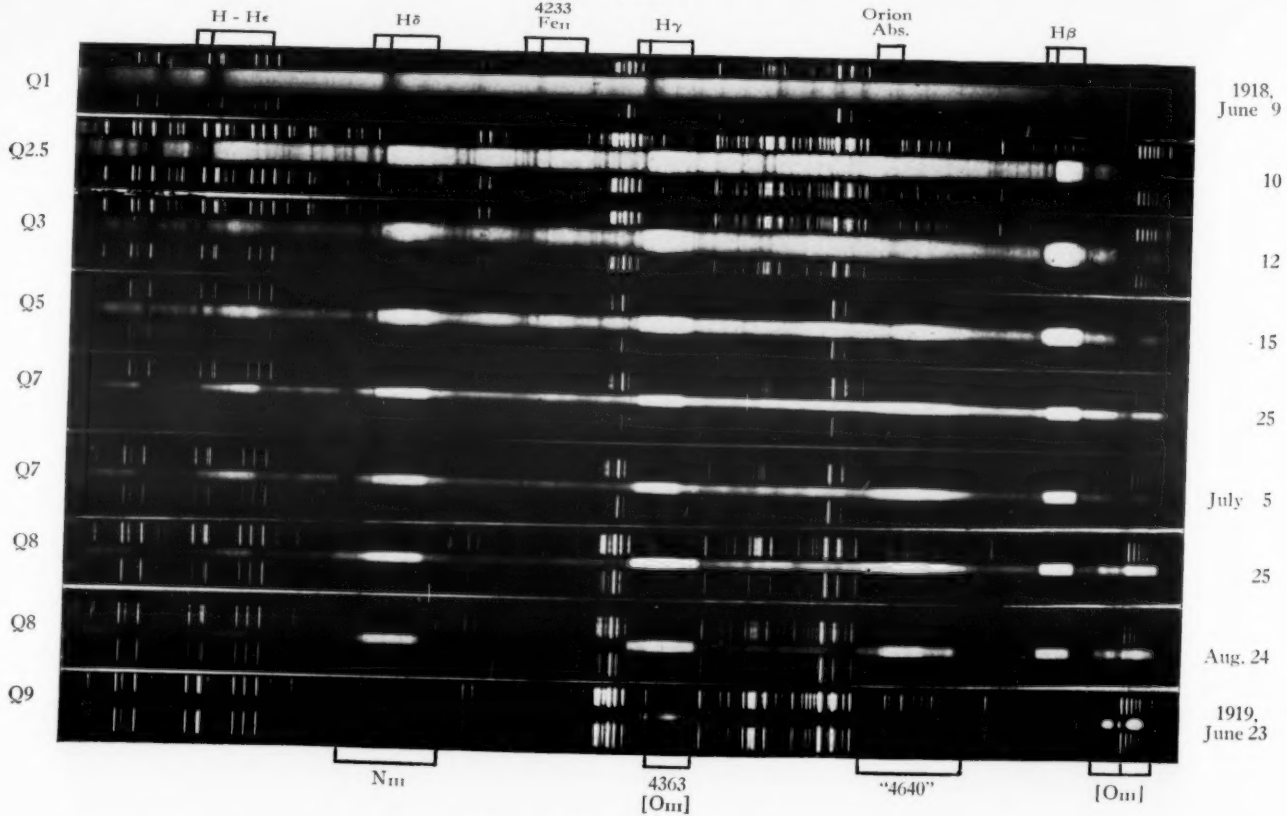


HD 217050

γ CASSIOPEIAE

PLATE V

PLATE V



SPECTRA OF NOVA AQUILAE 1918

ences of abundance, but can we explain the variable spectra in that way? We should feel better satisfied if a physical cause of varying abundance could be pointed out. So many variable spectra find an entirely satisfactory explanation in physical causes, as distinguished from stellar *chemistry,* that some skepticism is justified. Possibly we have here a phenomenon which is a special case of the formation and dissipation of a stratum of absorbing gas, but the problem is more difficult. In the "composite" Be spectra the variable lines are those associated in α Cygni; there is no such common characteristic identified in the variable lines of these Cor Caroli variables.

The Novae

The peculiar spectrum (and the variable spectrum) *par excellence* is that of the novae. The problem as a whole is so complex that we can consider here only a few aspects of it.

If we may judge from recent publications on novae, spectral class Q is either already defunct or just about to give up the ghost. Many students of these stars have doubtless arrived at the conclusion that it is easier to describe each nova spectrum as an entirely new thing than to attempt to fit it into a prearranged scheme of classification. Yet there is a rather surprising uniformity in the development of the majority of novae. The chief differences seem to arise from overlapping of the various stages in the fast novae and their separation in the slow ones. There are rather few real differences between the stages of development of slow and fast novae.[25]

The following numerical subdivision of class Q is not a deliberate attempt to resuscitate a spectral class whose demise is not likely to be greatly mourned. It is frankly the result of satisfying the urge to classify, and it is presented here for what it is worth. Typical stages of Nova Aquilae 1918 are shown in Plate V.

Class Q (Novae)

Q0. The early pre-maximum spectrum; usually a faint absorption spectrum with inconspicuous emission lines. A spectrum with strong bright bands (Nova Herculis, Dec. 13-18, 1934) would be designated Q0e. The Draper class most nearly resembling the nova spectrum could also be appended, thus: Q0A2.

Q1. The stronger absorption spectrum, without emission lines, in the immediate neighborhood of light maximum.

Q2. The early post-maximum spectrum, consisting of the principal absorption spectrum and associated emission lines of hydrogen, Fe II, and other enhanced metals.

Q3. The "diffuse enhanced absorption" stage. Besides the principal spectrum, there are now strong diffuse absorption lines of hydrogen, Fe II, and other enhanced metals, displaced considerably more than the principal spectrum.

Q4. A transition stage between Q3 and Q5.

Q5. The "Orion" stage. The principal and diffuse enhanced spectra are rather weak. A strong absorption system consisting of lines of He I, O II,

[25] McLaughlin, *Aph. J.*, **85**, 362, 1937.

NII, and other Orion lines, with associated emissions, is the dominant characteristic.

Q6. The "Eta Carinae" stage, characterized by forbidden emissions of FeII. Data now available indicate that this stage probably occurs only in slow novae.

Q7. The "4640 stage." Broad diffuse emission at λ4640,* and strong NIII absorption at λλ 4097, 4103. This stage is not distinctly developed in slow novae.

Q8. A transition stage to the nebular type.

Q9. The "nebular stage," characterized by strong emissions at λλ 4959, 5007 [OIII].

The manner of formation of the absorption lines in the early stages now seems to be pretty definitely indicated. The older expanding shell hypothesis of W. H. Pickering and Halm is no longer adequate, but it did serve a very useful purpose in converting a conservative and skeptical astronomical public to the concept of bodily outward motion of matter ejected explosively from the star. Even so, it would have made less progress had it not been helped by the actual visible motion of expanding nebulosity about novae for some years after maximum light.

In the original form of the hypothesis the part of the shell between the observer and the star produced absorption across the star's continuous spectrum. It has been pointed out,[26] however, that the additive effects of emission and continuous spectrum with absorption could never give a black line. The amount of energy absorbed could never be greater than the amount in the continuous spectrum of the star. The situation is entirely different if we postulate an outer absorbing stratum surrounding the region in which effective emission originates. Then the absorption would affect not only the continuous spectrum of the star, but also the light of the emitting gas directly behind the absorbing layer (provided there is no relative velocity of emitting and absorbing atoms). The evidence in the spectrum of Nova Herculis is quite clear in showing the influence of absorption overlapping the violet edges of the emission bands. The forbidden lines, having no absorption, showed greater velocities of approach on their violet edges than did the permitted lines whose violet edges were cut off by absorption.

In the early pre-maximum stages it is now quite certain that there is no true *shell* at all, but an expanding atmosphere which is continuous with the photosphere. The latter is simply an effective level at which opacity becomes great enough to prevent the direct escape of radiation to space. The photosphere is also travelling outward but, owing to the diminishing density as the gas expands, its rate of growth is not equal to that indicated by the radial velocities of the outward streaming atoms. This circumstance vitiates all calculations of dimensions and parallaxes of novae based on the observed velocities and increase of

*It should be pointed out that the diffuse band 4640 is not a very dependable criterion, as an illusory 4640 emission may result from blended Orion emissions during the Orion stage Q5.

[26] E. G. Williams, *Obs.*, **59**, 331, 1936.

brightness.* During the pre-maximum stage the great discordances of velocities of individual lines undoubtedly arise from differences of velocity at different depths in the outward rushing cloud. In Nova Herculis, during the first several days after discovery, the apparent velocity declined rapidly. According to the interpretation given here, the material ejected later left the star with a lower velocity. We are forced to this conclusion by the impossibility of such a rapid deceleration of the material by the gravitational field of any star of reasonable mass.

Just at maximum light we have a critical stage which results from the mechanism of opacity. Some time before light maximum the ejection of matter ceased, and the expelled gases were then in the form of a thick shell expanding about the stellar core. Until light maximum the optical thickness was great enough to produce an effective expanding photosphere. Just at light maximum the shell rather quickly passes the critical value of the optical depth below which it is pretty transparent except for its line absorption. This permits the emission from the far side of the shell to shine through, giving the complete emission bands whose red edges are displaced nearly the same amount as the absorption on their violet edges.

The other absorption systems are not so well understood. The place of origin of the diffuse enhanced absorption system is not entirely clear. The manner of its emergence suggests the gradual formation of an atmosphere where none existed before, so that it is possibly a new shell coming out from the star with higher velocity. On the other hand, a great deal of material ejected from the star in the early pre-maximum stage must have passed through the regions of effective emission and absorption and on into an outer region where it became spectroscopically inert. Is there any possibility of this material becoming spectroscopically active again and forming a discrete shell moving with a definite velocity? Similar questions may be raised in regard to the Orion absorption spectrum. In this case, however, an origin near the star seems to be indicated. The color temperature of the nova in this stage is roughly that of a class B star, and in the case of Nova Herculis the Orion absorptions exhibited variations of velocity which were suggestively correlated with the subordinate light variations.

One formerly puzzling aspect of the diffuse enhanced absorption spectrum deserves mention here. Although its lines are very strong they are relatively few in number. The great intensity of those lines which are found would lead one to expect many others which do not appear at all. While it is too early to claim that the question is definitely answered, there is now a promising clue as to its meaning. Briefly, it appears to be a gradient effect. The diffuseness of the lines is clearly due to Doppler broadening, since it affects strong and weak lines alike,

*Such calculations were made by the author (*Astron. Jour.*, **45**, 145, 1936) for several bright novae. Without exception they gave luminosities considerably higher than those calculated by other methods.

regardless of their origin. The only Doppler broadening which appears possible in this case is that due to turbulence,—and we may certainly expect turbulence in a nova if anywhere. Simple inspection indicates that the turbulent velocities are probably of the order of 100 km/sec or more. Under these circumstances we should get an exaggeration of the abnormal intensity gradients found by Struve and others in ϵ Aurigae, 17 Leporis, and other stars.[27] The direction of the effect in those spectra is to increase the intensities of the strongest lines and suppress the weak ones. In the diffuse enhanced spectrum of a nova this has gone so far that the weaker lines are completely missing, and those of moderate intensity are much weakened.

It would be of great interest to observe closely the development of a nova of moderate rate. The fast ones have not shown the Eta Carinae stage; the slow ones seem to lack the strong N_{III} absorption associated with the "4640 stage." Possibly a detailed photometric analysis of the spectra of fast and slow novae would show traces of the apparently missing features in both, and a star of intermediate rate might show both well developed.

Some Peculiar M-type Stars

Only brief notice can be taken of a group of remarkable spectra recently recognized. The peculiar bright-line spectrum of Z Andromedae, with its associated nebular lines, long appeared unique, and its light variations suggested a relation to the novae. On the other hand, it exhibited little similarity to that of the old nova T Coronae, which was of class M with helium emission. Merrill's [28] discovery of four class M stars with helium and nebular emissions, and the detection of the TiO bands in the spectrum of Z Andromedae[29] appears to bridge the gap between these apparently dissimilar objects. To complete our mental confusion, two well-known long-period variables appear to be related to these stars. R Aquarii[30] with its variable Be component and nebular emissions is evidently very similar to them, and o Ceti with a dwarf Be companion is only one step removed from the group.

Another interesting group of class M stars have conspicuous forbidden emission lines of iron. The full list cannot be given here, but the brighter members are worth enumerating. The most thoroughly studied is VV Cephei which has a strong B-type spectrum in the ultra-violet. In this case the forbidden lines do not share the orbital motion of either star, but remain fixed, indicating an origin in an extensive cloud about the whole system. The star Boss 5481 has an even brighter B-type companion; the class M spectrum is partly obliterated throughout the photographic region. Boss 1985 has very strong forbidden iron emissions and a very faint ultra-violet extension, indicating an early-type compan-

[27] *Aph. J.*, **79**, 409, 1934.
[28] *Aph. J.*, **77**, 44, 1933.
[29] Hogg, *Publ. Amer. Astr. Soc.*, **8**, 14, 1934.
[30] Merrill, *Aph. J.*, **81**, 312, 1935.

ion. Finally, the B-type companion of Antares shows the forbidden iron lines.[31] If the iron is related to these stars as it is to the VV Cephei system we might have here an iron nebula of measurable extent. These four occurrences of forbidden iron lines in systems composed of M and B-type stars are most suggestive. Possibly the association is necessary to the production of the lines: a large M-type star to eject the iron atoms, and a B-type star to furnish the requisite excitation.

Conclusion

The study of peculiar stellar spectra has given both encouragement and disillusionment to the astrophysicist: encouragement because some problems, such as that of the Be stars, show signs of yielding to analysis; disillusionment because they have so far failed to give a clearly dependable clue to stellar evolution. When the bright lines faded from the spectrum of Pleione the evolution of B-type stars from the bright-line nebulae was widely believed. The association of Orion stars with such nebulae was favorable to that view, and the fading of emission suggested the assimilation of the last remaining bit of glowing gas into the structure of the star. The downfall of the old single-line theory of stellar development and the explanation of nebular luminosity as due to excitation by the hot stars left the Be stars "out on a limb." With many more cases from which to generalize, we can now conclude that there are no signs of permanent development in any given direction. Several stars have lost their emission lines only to regain them, and the gathering of more data only emphasizes the cyclic character of most of the changes. Even the novae may be cyclic in their behavior; two authentic cases of repetition are now on record, and the U Geminorum stars show every indication of being very mild and frequently recurring novae.

No far-reaching general conclusion can be drawn at this time. This particular field of stellar spectroscopy is still in the stage of gathering data and attempting to classify and correlate the material. At the same time, the general characteristics of peculiar spectra are known well enough to justify some attempts at theoretical interpretations. Perhaps the most important conclusion I can draw is that there is still plenty of work for telescopes of moderate dimensions to do in following the changes of these interesting peculiar and variable stellar spectra.

[31] Wilson and Sanford, *Publ. A. S. P.*, **49**, 221, 1937.

The Observatory, University of Michigan, May, 1938.

The Harvard Conference on Cepheid Variables

A conference on problems of Cepheid variation was held at the Harvard Observatory on April 15, 1938. In introduction Dr. Cecilia Payne-Gaposchkin presented a general survey of the knowledge so far obtained of the nature of Cepheids, the types of problems involved, and the questions still to be answered. Reports were made on current or recently completed researches at the Observatory. The following paragraphs give abstracts of most of the papers.

PROPERTIES OF STARS AT THE MINIMA OF PERIOD FREQUENCY

By Sergei Gaposchkin

The properties of stars in the period intervals: $0^d.06$ to $0^d.29$ (20 stars); $1^d.01$ to $1^d.65$ (15 stars); $8^d.03$ to $9^d.84$ (17 stars); and $38^d.72$ to $57^d.22$ (11 stars) have been investigated on the basis of the published photometric observations. By means of the parameters describing the form of the light curve, as published in *Harvard Reprint* 143 (*P.N.A.S.*, **24**, 1, 1938), results have been obtained which fully confirm those given in that paper and also in the *Publications of the American Astronomical Society* (**9**, 39, 1938).

The minima of period-frequency are at $0^d.11 \pm 0.05$, $1^d.52 \pm 0.11$, $9^d.2 \pm 0.4$, and 52^d. The maxima are at $0^d.12$, $0^d.49$, $5^d.0$, and $12^d.5$.

The light curves of 92 cluster type variables have also been examined. In the interval from $0^d.345$ to $0^d.733$ the positions of the humps on the light curves show a definite tendency to change with the period, *in the reverse direction* to that first established by Hertzsprung for periods between 6 and 22 days.

ON THE STRUCTURE OF CEPHEID ATMOSPHERES

By Donald H. Menzel

The interpretation of the variable radial velocities of Cepheid variables as a pulsation phenomenon has led to many interesting consequences—and difficulties. The observational data secured by R. H. Curtiss, D. B. McLaughlin, and others associated with the Observatory of the University of Michigan have shown that the velocity curves derived from different lines of the same spectrum are far from identical. Jacobsen showed that certain of these difficulties may arise from the low-dispersion spectra used by the Michigan investigators. Blends are a serious menace to accurate determination of a velocity curve, especially when the spectral type of the star is variable. But the effect discovered by Curtiss appears to be none the less real.

The lines of a stellar spectrum are divided into several groups, and

the mean velocity curve derived for each group. As a criterion for dividing the lines, Curtiss used Mitchell's measurement of the heights to which the various lines were observed in the chromosphere. The interpretation, then, of the various velocity curves was that they represented the actual motion of high, intermediate, and low levels of the Cepheid atmosphere. The observed phase lag of the high-level lines was attributed to the possibility that the compression wave reached the high levels last.

In the light of newer observation and theory, the difference in form of velocity curve cannot be explained in so simple a fashion. Dr. F. L. Whipple pointed out to me some years ago that the range of expansion, which is simply the area between two ordinates of the velocity curve, is very different for the various groups of lines. An atmosphere, starting out with the elements well mixed, would become a stratified planetary nebula at maximum size, with a hydrogen envelope far outside the rest of the star. At minimum the hydrogen would be the innermost envelope. The secondary variations cannot therefore be assigned to compression waves. Other effects, such as darkening at the limb, presence of higher modes of vibration, or variable turbulence might affect various lines differently. The correlation between form of velocity curve and chromospheric height may well be a correlation between curve form and line intensity. I have shown that chromospheric height is determined chiefly by the intensity of the line and that there is no evidence for stratification in the chromosphere, beyond a slight tendency for the lighter elements to show smaller intensity gradients.

I am inclined to the view that part, at least, of the phenomenon discovered by Curtiss must be assigned to the effect of turbulence. A variable geyser-like prominence activity in the extended chromosphere of a Cepheid would produce distortions of the velocity curve, without implying actual separation of the atmosphere into stratified layers. The minute displacements of solar lines, found by St. John, and interpreted by him as vertical atmospheric currents, were a function of line intensity. The greater but analogous shifts found for the group of so-called "pseudo-Cepheids" indicates that one cannot expect to derive identical velocity curves for lines of different intensity. In interpreting the spectra of Cepheids and other giant stars, the observer might well recall that the absorption lines probably arise chiefly in layers where chromospheric conditions obtain. The questions of turbulence and prominence activity are added to the already difficult problem of ordinary pulsation and radiation transfer.

THE RELATION OF FORM OF LIGHT CURVE TO PERIOD FOR CEPHEIDS IN THE LARGE MAGELLANIC CLOUD

By Jenka Mohr

The Large Magellanic Cloud, with over thirteen hundred known variable stars, offers excellent homogeneous material for the study of the

light-curve characteristics of Cepheids. Of especial interest is the problem of the correlation of period with form of light curve. On the basis of data obtained from galactic Cepheids, a number of observers, especially Hertzsprung, have discussed the appearance of abrupt changes in the rate of increase or decrease of light, and particularly the correlation of period with the phase at which such changes occur. Although the stars for which adequate mean light curves were obtainable were few, and the observations not always homogeneous, indications of such correlation were consistent.

Twenty-four Cepheids in the Large Cloud, with periods between 4.9 and 28.2 days, were twice measured by Miss Virginia McKibben on over two hundred plates taken with the Bruce 24-inch refractor at the Boyden Station. Preliminary periods were corrected and mean curves derived, with points taken for every five observations. In order to evaluate the irregularities due to observational errors, alternate mean points were used to obtain two independent curves, which were then combined.

All of the variables studied show secondary waves in the light curves. The Cepheid with a period of 4.9 days shows a very slight wave but no perceptible "hump." The curves for stars with periods between five and nine days have such humps on the descending branch, which approach the maximum phase as the period increases. Three stars, with periods of 9.5, 10.9, and 11.2 days, show double maxima. Curves for stars with periods between 11.8 and 15.5 days exhibit humps on the ascending branch, and frequently secondary humps on the descending branch. The longest period studied, 28.2 days, has a light curve with only a slight irregularity on the descending branch.

An attempt to establish a correlation between range and period brings no positive conclusion. A slight correlation is indicated, but is found to depend on three stars, all with amplitudes subject to suspicion. One star probably has a very close companion, and the range is therefore masked; the two other stars have light curves with double maxima, by which true ranges may again be disguised. With these three omitted, there is no noticeable progression of range with period for the twenty-four stars.

Further measures are being made on Large Cloud variables, to establish more precisely the relation of period to phase of irregularities on the light curve. An attempt is also being made to determine whether the deficiency in number of stars with periods of about nine days holds in the Cloud as in the local Galaxy.

THE LIGHT CURVE OF SU CASSIOPEIAE

By Daniel Norman

Both Nijland and Parenago have indicated that the shape of the light curve of SU Cassiopeiae varies secularly. A comparison of the recent photographic light curve by Kox with the early photographic curve by

Parkhurst, and a similar comparison of the visual curves by Zverev and by Müller and Kempf, indicate clearly that the light curve is becoming increasingly asymmetric. There is also a slight indication that the period is decreasing, but this must be confirmed by more observations before it can be accepted. The amplitude of the variation is itself variable—apparently because of the presence of a secondary period of the type found for RR Lyrae. A photoelectric study of SU Cassiopeiae would be exceedingly valuable; an extensive spectrophotometric study will soon be completed by the writer.

ON THE STABILITY OF PULSATIONS

By M. Schwarzschild

1. Eddington (*Inn. Aufbau d. Sterne,* p. 242, 1928) has shown that the pulsation of a Cepheid could be maintained either by a variable energy source which increases with increasing temperature or by a variable absorption coefficient which increases with increasing temperature. These two mechanisms differ in that the first could probably act under very general conditions, whereas the second can act only if the temperature of the interior is about the ionization temperature of an electron shell of one of the most abundant elements. Since the observations show that only stars of rather special characteristics can pulsate, it seems reasonable to assume that the first mechanism alone is not sufficient, and that the second must help maintain the pulsation. From this it would follow that only stars with certain central temperatures can pulsate. Since the central temperature of Cepheids decreases strongly with increasing period (Eddington, *M.N.*, **92**, 479, 1932), it does not seem possible that a single ionization step can be responsible for all observed pulsations. But the observed division of the Cepheids into three main groups—the cluster-type variables (Per. $<1^d.5$), the short-period classical Cepheids ($1^d.5 <$ Per. $< 9^d$), and the long-period classical Cepheids (Per. $>9^d$)—suggests that three different ionization steps are acting, each in one of the three groups. A comparison of the temperatures in the interior of Cepheids with the ionization temperatures of oxygen and iron (Hartree, *Proc. of Camb. Phil. Soc.*, **22**, 473, 1924), which may be fairly representative of the material in the interior since there hydrogen and helium are already totally ionized, indicates the possibility that in the first group the L-shell of iron and the K-shell of oxygen, in the second group the inner part of the M-shell (3S- and 3p-electrons) of iron, and in the third group the outer part of the M-shell (3d-electrons) of iron and the L-shell of oxygen, provide the necessary ionization steps.

2. The above-mentioned processes (which strengthen the pulsation) and the damping processes must be very closely balanced in order to make the pulsations as stable as they are observed to be. A possible explanation of this stability is that for small amplitudes the strengthening processes are greater than the damping processes, but that with increasing amplitude the damping becomes stronger. Then a Cepheid

could pulsate stably only with a certain amplitude, for which the balance is just reached. The value of this stable amplitude will depend on the characteristics of the star, and may therefore be taken as a function of the mean absolute magnitude and the mean spectral type, e.g., the amplitude of a Cepheid would be a function of the position of the Cepheid in the Hertzsprung-Russell diagram (Kuiper, *Harvard Bull.* 903, 1, 1936). The available observations do not seem to be sufficient to test this possibility directly. The period, however, is very probably a strict function of the absolute magnitude and the spectral type (because of the period-density law), so that one of the two star-parameters can be replaced by the period. Indirect tests consist therefore in the investigation of (a) the amplitudes of the galactic Cepheids as a function of spectral type and period, and (b) the amplitudes of the Cepheids in ω Centauri and in Messier 3 as a function of magnitude and period. These tests seem to indicate the presence of the effect.

A FURTHER STUDY OF CEPHEIDS THROUGH A GALACTIC WINDOW

By Harlow Shapley

Earlier studies at the Harvard Observatory had shown in a low galactic region (longitude 300°, latitude —15°) an unusually high number of external galaxies. Since the region is less than 30° from the direction to the galactic center, a special study was made of the variable stars over an area of some 80 square degrees. It was found that the total space absorption in this direction probably does not exceed half a magnitude (photographically), and that a considerable number of the cluster-type Cepheids discovered and measured lie in what may be called the trans-center region of the Milky Way. The result indicates that the heavy absorption in the Milky Way may be chiefly localized in absorbing clouds of nebulosity, and that the evidence is slight for the existence of an extensive uniform absorbing layer parallel with and near the galactic plane.

The work has now been extended by means of a study of galaxies and variable stars in an overlapping region centered on galactic longitude 307°, latitude —20°. In an area of 80 square degrees, about 700 galaxies of magnitude 17.1 and brighter have been found. If the normal average density throughout the region is like that of the northwestern quadrant of the south galactic cap (see *Harvard Circular* 423, 1938), we conclude that there is practically no space absorption in excess of that at the galactic pole; but if the normal average density of galaxies is like that of the southeastern quadrant of the south galactic cap, then the space absorption is about half a magnitude more than at the galactic poles.

In the course of the study 332 new variable stars have been found, chiefly by Miss Boyd. Supplementing the work with the 10-inch camera at the Boyden Station, we have used the Bruce refractor and the

60-inch reflector. Of the new variables, nearly 200 are of the cluster type. They show little galactic concentration, but there is some indication that the number increases in the direction toward the galactic center. Their magnitudes indicate that a part of this exploration through the galactic window concerns seventeenth magnitude objects that lie well beyond the galactic center. With appropriate correction for space absorption, the remotest Cepheids in the new field are about twenty kiloparsecs distant (if we take the median absolute magnitude to be zero). The 60-inch reflector, showing stars to the nineteenth magnitude in five parts of the field, fails to disclose more distant variables, thus indicating that in latitude —20°, longitude 307°, we apparently have come to the boundary of the galactic system.

SECONDARY PERIODS IN CEPHEIDS

By T. E. Sterne

The residuals of the magnitude of a cluster-type Cepheid from its mean magnitude curve may contain real secondary periodicities, which are not mere multiples or submultiples of the fundamental period according to which the mean magnitude curve was obtained. A secondary period must usually produce a periodic variation in the range of the variable, and also a periodic term in its ephemeris. The notion of secondary periods is therefore essential, probably, to an understanding of those properties which are periodic in periods incommensurable with the fundamental period. Secondary periods may be fairly common among cluster-type Cepheids. A discussion of the secondary period of δ Scuti, observed photoelectrically by Fath, has appeared in *Astrophysical Journal*, **87**, 133, 1938.

Secondary periods are also of importance in their probable bearing upon the pulsation theory, and upon density distributions. It is generally known that, in the pulsation theory, the period of the lowest mode of radial vibration depends upon the mean density, the stellar model, and the value of the constant γ in the law $P \propto \rho^{\gamma}$ that describes the dependence of the pressure P upon the density ρ at a single point in the vibrating star. As γ is varied from 4/3 (the smallest value consistent with stability) to 5/3 (the greatest for any known material), the period of the lowest radial mode decreases, for any given model and mean density, from infinity to a finite lower limit. Any period between these limits can be obtained by a suitable choice of γ, even when the model and the mean density are held constant. On the other hand, it has been shown dynamically in *Monthly Notices*, **97**, 582, 1937, that the periods of radial modes of successively higher orders (i.e., with increasing numbers of nodal surfaces) are decreasingly sensitive to the value of γ. A knowledge of the periods of higher radial modes therefore gives more information about the stellar model than does a knowledge of the period of the lowest mode. Certain ratios between the periods of different modes cannot easily be reconciled with the radial pulsation theory.

Although it is reasonable to attempt to explain incommensurable periods, in the same cluster-type Cepheid, as radial modes of different orders, it should be borne in mind that there may be other possible explanations. It does not appear to be possible to explain a secondary (or a fundamental) period as a purely radial vibration forced by the gravitational attractions of external bodies. By the dynamical theory of vibrations, any displacement of a star from its equilibrium configuration can be expressed in terms of "normal" coördinates, which can be made to oscillate by periodic changes in the corresponding "normal" components of the external force. The gravitational forces due to external bodies contain no purely radial components, and cannot therefore excite purely radial vibrations. Such forces must produce spherical harmonic vibrations.

VARIABLE STARS IN A HIGH LATITUDE FIELD

By S. L. Thorndike

A survey is in progress of variable stars in an area of about 63 square degrees, the equatorial and galactic coördinates (1900) of the center of which are:

$$\alpha = 21^h, \quad \delta = +5^\circ; \qquad \lambda = 22^\circ, \quad \beta = -28^\circ.$$

Most of the plates used are 45-minute exposures obtained with the 10-inch Metcalf telescope (MF) at Bloemfontein, and reach about $16^M.3$.

By means of contact comparisons of 19 negatives with 2 positives, 72 stars have been identified as probably variable. SU Del, T Equ, and 6 other stars, previously reported as variable by other investigators and independently examined during this survey, are included.

A preliminary survey of 49 stars suspected of variability, within an area of about 42 square degrees, has been made: the variability of 24 is undoubtedly real, and tentative periods for 9 have been computed. Among the 24 confirmed variables, 5 have been provisionally classified as having long periods, 4 as classical Cepheids, 5 as cluster-type Cepheids, 1 as an eclipsing binary, and 9 were doubtful.

A more thorough study of all 72 suspected variables is now being made.

PRESSURE EFFECTS IN CEPHEID ATMOSPHERES

By Fred L. Whipple

In the pulsation theory of Cepheid variability the observed phase relationship between the temperature and the radius has been explained by the presence of running waves in the Cepheid atmosphere. Such running waves can exist only if the atmosphere is supported chiefly by some mechanism other than that of gas pressure. If a Cepheid atmosphere is supported by some other mechanism, the variations in the gas and electron pressures with phase can be of considerable amplitude. Observations of line-intensity variations in δ Cephei suggest that the electron pressure does vary over a considerable range.

There are various possible supporting mechanisms. In the extended atmospheres of the supergiant components of ζ and ϵ Aurigae, light pressure is probably insufficient to give the required support. Electrostatic and magnetic processes so far suggested meet with serious objections. Some process of turbulence seems to be the most probable source of atmospheric support in giant and supergiant stars.

The Lunar Eclipse of 1938 May 14 and its Saros Series

By ALEXANDER POGO

The lunar eclipse of 1938 May 14 was the last total eclipse of a remarkable saros series, L42. The first total eclipse of the lunar saros series L42 occurred in 1505, on Aug. 14. Fig. *a* (Pl. VI) reproduces one of the earliest printed predictions of the eclipse of 1505 Aug. 14; the Latin edition of the Calendar of Regiomontanus was printed by him in Nuremberg, between 1472 and 1474; the facsimile was made from the Library of Congress copy of Hain 13775 (No. 137 in the Thacher collection of incunabula; the little circle and the white lines on the black disk are part of the watermark). Regiomontanus gives $8^h\ 18^m$—counted from Nuremberg apparent noon—as the predicted time of the middle of the eclipse of 1505 August 14, and $1^h\ 43^m$ as half of its duration. The longitude of Nuremberg is 44^m E of Greenwich, the equation of time amounted to about 3^m, and the moment of the middle of the eclipse, as predicted by Regiomontanus with the aid of the Alphonsine Tables, is equivalent to $19^h\ 37^m$ counted from Greenwich mean midnight; this XVth-century prediction compares favorably with the results of modern computations, *viz.*, $20^h\ 2^m$ U.T. (Oppolzer's *Canon*), $20^h\ 4^m$ U.T. (Schroeter's *Spezieller Kanon*), or $20^h\ 7^m$ U.T. (Table I of this paper). According to Regiomontanus, 103^m elapsed between the middle of the eclipse and the beginning or the ending of the partial phase; Oppolzer's *Canon* gives 102^m; Schroeter's *Spezieller Kanon*, 102^m; the tables of Schram[1] and of Neugebauer[2], 103^m; Neugebauer's improved tables[3] yield 109^m.

The first partial eclipse of the lunar saros series L42 occurred in 1379, on May 31; the last partial eclipse of the series is scheduled for 2064 July 28; the run of umbral eclipses of the lunar saros series L42 will, therefore, consist of 39 eclipses only. Of the 81 lunar saros series whose umbral runs are complete within the limits of Oppolzer's *Canon*, the saros series L42 has the distinction of having the shortest umbral run, *viz.*, 39 eclipses; among the 81 solar saros series which have umbral

[1] Tafeln zur Berechnung der näheren Umstände der Sonnenfinsternisse. *Denkschriften d. Akademie*, 51, Wien, 1886.
[2] Astronomische Chronologie, Berlin, 1929.
[3] Zur Berechnung der Mondfinsternisse. *Astr. Nachrichten*, 243, 245-48, 1931.

runs falling entirely within the limits of Oppolzer's *Canon*, only one series, S89, had an umbral run (878 May 6 Julian to 1761 October 27 Gregorian) of 39 eclipses. The distribution of partial and total eclipses within the umbral run of the lunar saros series L42 is as follows: 7 initial partial eclipses, between 1379 May 31 and 1487 August 4; 25 total eclipses, from 1505 August 14 to 1938 May 14; and 7 terminal partial eclipses, from 1956 May 24 to 2064 July 28.

While the 39 umbral eclipses of the lunar saros series L42 will establish a record run of 685 years, about fifteen centuries will elapse between the first initial and the last terminal penumbral eclipses of the series. The first eclipse of the initial penumbral run occurred, probably, in 982, on October 5; it is possible, however, that the full moon of 964 September 24 touched the penumbral cone; in Table I, the eclipse of 982 October 5 is considered as the first eclipse of the series, and a question mark calls attention to the ambiguous status of the ecliptic syzygy of 964 September 24; it must be kept in mind that an uncertainty amounting to about 0.03 of the moon's diameter cannot be avoided in computing the magnitudes with the aid of Neugebauer's ecliptic tables. The last eclipse of the terminal penumbral run of series L42 will occur, probably, in 2479, on April 6 or April 7; it is possible, however, that the full moon of 2497 April 17 will touch the elusive fringe of the pen-

TABLE I

LUNAR SAROS SERIES L42

		Date	GCT	J.D. GMT	Magn.	λ_z	ϕ_z	P	L	γ
?	s	964 Sep 24	8^h48^m	2073 425.87	−1.06	−134°	+ 3°	18°.2	6°.5	+1.59
1	a	982 Oct 5	16 57	2080 011.21	−0.99	+104	+ 7	17.7	17.3	+1.55
2	a	1000 Oct 16	1 5	2086 596.55	−0.99	− 20	+11	17.5	28.3	+1.55
3	a	1018 Oct 27	9 26	2093 181.89	−0.99	−146	+15	17.5	39.3	+1.55
	a	.....								
	a	.....								
22	a	1361 May 20	15 17	2218 303.14	−0.06	+130	−21	11.1	247.0	+1.04
23	p	1379 May 31	21 55	2224 888.41	+0.06	+ 31	−23	10.3	257.4	+0.97
	p	.....								
	p	.....								
29	p	1487 Aug 4	13 22	2264 400.06	+0.98	+161	−15	4.9	320.2	+0.47
30	t	1505 Aug 14	20 7	2270 985.34	+1.13	+ 59	−12	4.0	330.7	+0.38
	t	.....								
	t	.....								
54	t	1938 May 14	8 40	2429 032.86	+1.11	−131	−19	355.8	232.8	−0.40
55	p	1956 May 24	15 28	2435 618.14	+0.96	+127	−21	354.9	243.3	−0.48
	p	.....								
	p	.....								
61	p	2064 Jul 28	7 45	2475 129.82	+0.08	−115	−19	349.6	305.9	−0.97
62	a	2082 Aug 8	14 37	2481 715.11	−0.05	+142	−16	348.7	316.5	−1.04
	a	.....								
	a	.....								
84	a	2479 Apr 7	0 7	2626 592.50	−0.95	− 1	− 7	342.0	197.4	−1.54
?	s	2497 Apr 17	8 7	2633 177.84	−1.04	−122	−11	341.5	208.2	−1.58

s — syzygy; a — penumbral eclipse (appulse); p — partial ecl.; t — total ecl.
The dates of the second part of the table are given in the Gregorian calendar.

ber 24 touched the penumbral cone; in Table I, the eclipse of 982 Octo-

umbra. For the computation of the eclipses of the remote future, I have made use of my extrapolation tables based on Schram's Cyklentafel; the moment of mid-eclipse computed in this manner may be in error by about a quarter of an hour, and since the eclipse of 2479 will occur, according to the computations, at $0^h\ 7^m$ U.T., *i.e.*, near Greenwich mean midnight, this eclipse of short duration may fall either on April 6 or on April 7; the terrestrial longitude of the point having the eclipsed moon in the zenith may be in error by about 4°; the magnitude is, probably, correct within 0.05 of the moon's diameter.

The checking of these long-range predictions of the circumstances of the eclipse of 2479 April 6/7 and the determination of the ecliptic nature of the syzygy of 2497 April 17 must be left to the astronomers of the XXVth century. It is safe to state, however, that the lunar saros series L42 will consist of 84 or 85 eclipses; no statistical data on the number of eclipses in lunar saros series of very long duration are available, but, among the 81 solar saros series which begin and end within the limits of Oppolzer's *Canon*, one series only, S41 (—839 August 24 to 676 February 19) consisted of 85 eclipses, and only one series, S88 (—727 August 15 to 770 Jauary 31) consisted of 84 eclipses. Thus, the lunar saros series L42, in addition to establishing a record for the shortest run of umbral lunar eclipses, has the distinction of being one of the few saros series—lunar or solar—characterized by a sesquimillennial interval between the first initial and the last terminal penumbral eclipses of the series.

* * * *

The predicted circumstances of the total lunar eclipse of 1938 May 14 are summarized in Table II and are illustrated by the diagram reproduced in Figure 1. Reports concerning the observation of the initial penumbral phase of the eclipse of May 14 have reached me from various points located in the Eastern, the Central, and the Mountain Standard Time zones; partial or total (Florida, Illinois) interference by clouds or rain was the rule rather than the exception (it was generally clear in New England); I hereby express my thanks to those who wrote to me —about the eclipse, about the double or single corona, or about the

TABLE II

CIRCUMSTANCES OF THE TOTAL LUNAR ECLIPSE OF 1938 MAY 14
(According to the *American Ephemeris*)

	d	h	m	
Moon enters penumbra	May 14	5	44.3	U.T.
Moon enters umbra		6	56.6	
Total eclipse begins		8	18.1	
Middle of the eclipse		8	43.5	
Total eclipse ends		9	9.0	
Moon leaves umbra		10	30.7	
Moon leaves penumbra		11	43.3	

Magnitude of the eclipse = 1.102 (Moon's diameter = 1.0)

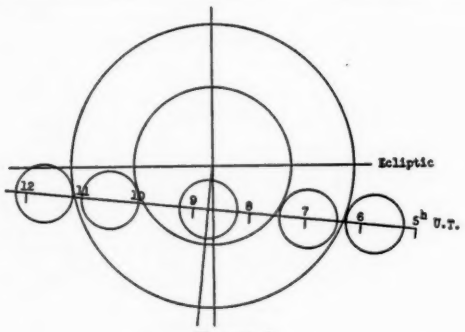


FIGURE 1

THE TOTAL LUNAR ECLIPSE OF 1938 MAY 14

clouds. The results of the available naked-eye observations are summarized in Table III. The inner layers of the penumbral cone were remarkably dark, making possible a rather early detection of the darkening of the disk; the "flat-tire" appearance of the eclipsed limb was noticed by several trained observers a quarter of an hour before the beginning of the umbral phase. At the predicted moment of contact

TABLE III

INITIAL PENUMBRAL PHASE OF THE ECLIPSE OF 1938 MAY 14

	U.T. h m	Magn. of phase	Approx. dist. from phys. umbra
Moon enters penumbra	5 44	—1.08	32′
Darkening suspected	6 30	—0.40	12
" certain	6 34	—0.34	10
" conspicuous	6 39	—0.26	8
Flattening suspected	6 39	—0.26	8
" certain	6 46	—0.16	5
" conspicuous	6 50	—0.10	3
Moon enters umbra	6 57	0.00	0

with the physical umbra, the dark inner layers of the penumbra made it impossible, for this observer, to see the eclipsed limb even with the aid of a Zeiss Telita (6×) binocular.

The photographs reproduced in Figure *b*, Plate VI, were put at my disposal through the courtesy of Mr. Oscar E. Monnig. The original photographs were taken by the Texas Observers, at Fort Worth, Texas, with the Robinson telescope of the Harvard College Observatory, a 4-inch Clark refractor on loan to Las Estrellas Observatory; exposure time, 1/10 second; Eastman Panchro-Press film; the diameter of the moon is 13 mm on the original negatives; taken through thin clouds. The photograph taken at $6^h\,53^m.3$, more than three minutes before the beginning of the umbral phase, reveals the complete obscuration of the limb eclipsed by the dark inner layers of the penumbra. The photograph

PLATE VI

FIGURE a

THE TOTAL LUNAR ECLIPSE OF 1505 AUGUST 14

(From: Regiomontanus, Calendarium, Nuremberg, ca. 1474)

By courtesy of the Library of Congress

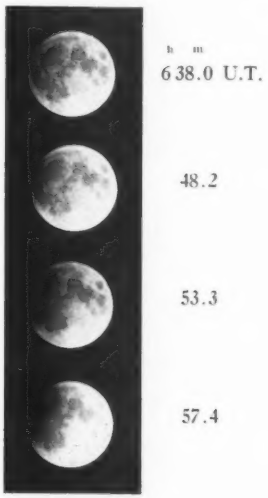


FIGURE b

INITIAL PENUMBRAL PHASE OF THE LUNAR ECLIPSE OF 1938 MAY 14

North is at the top.

(From photographs by the Texas Observers, Fort Worth, Texas)

taken at $6^h\ 57^m.4$, less than a minute after the moon entered the umbra, shows that—to the camera as to the eye—a shallow partial eclipse looks exactly like a close appulse. Modern nautical almanacs recognize the existence of the penumbral phases preceding and following the umbral phases of lunar eclipses; they recognize the existence of penumbral solar eclipses; but they refuse to acknowledge the existence of penumbral lunar eclipses; in this respect they are, like Regiomontanus, unable to break with mediaeval traditions.

CARNEGIE INSTITUTION
WASHINGTON, D. C.

Two Inexpensive Orreries

By ROY K. MARSHALL

Many teachers of astronomy and perhaps some advanced amateurs have often wished for a good orrery or mechanical planetarium. The fairly numerous examples of such instruments to be seen in various astronomical exhibits appear to be so complicated that any thought of constructing one is entertained but a moment. Diagrams of a few are available in print, but as soon as a zealous reader encounters a gear with 137 teeth he gives up in despair, if he knows anything about the cost of special machine work.

To be sure, to represent the motions of the planets with an accuracy as great as that of the Zeiss optical planetarium requires rather weird numbers of teeth in the gears of the various trains. It is to be seriously doubted, however, if the average orrery will be used for purposes of prediction; its greatest value, rather, is to demonstrate and clarify certain topics in planetary astronomy. Therefore, it seems that it may be useful to describe two mechanical planetaria which can be built with standard gears, readily obtainable for a few cents each; the resultant motions will match those of nature within a reasonable tolerance. I must confess that I have built neither one; I contemplate both, however, and will appreciate any improvements which may be suggested.

ORRERY OF THE TERRESTRIAL PLANETS

The simpler instrument is to display the (circular) orbital motions of the planets Mercury, Venus, Earth, and Mars. It is well known that in any such model some sacrifice must be made, in the matter of scale; it is impossible to represent the sizes of the bodies and their distances from the sun on the same scale and it is quite annoying to try to represent the sizes of the sun and the planets on the same scale. The model will demonstrate the configurations of the planets (oppositions, conjunctions, quadratures, greatest elongations) and the reasons for direct and retrograde motions; in addition, the interesting phenomena of the phases of the planets can be shown if the sun is made an incandescent bulb, and the model exhibited in a relatively dark place. So the sun might be in-

dicated by a spherical light globe, about 2 inches in diameter. The planets can be made of various materials, depending upon the ingenuity of the one who is making the instrument; their relative sizes can be indicated, perhaps with the earth an inch in diameter. The distances of the planets from the sun can be represented in proper proportion; a suggested scale is 10 inches to the astronomical unit, so the entire orrery can operate in a space no more than a yard across.

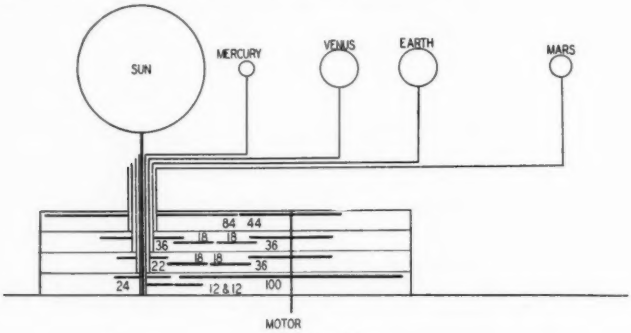


FIGURE 1
ORRERY OF THE TERRESTRIAL PLANETS

Standard gears (for example, Boston Gear Works, Inc., whose catalogue I have used throughout) are made of predetermined sizes and numbers of teeth. I have chosen small brass gears, 14½°, 48 pitch, with ⅛-inch face. If we could specify the size of the gear which has a certain required number of teeth, the gearing could be done directly from the power shaft to the driven shaft; standard gears make it necessary to interpose idlers to link the driving to the driven gears, for at least three of the motions.

The trains for the four planets considered are given in the table below; the first gear is attached to the motor shaft, the next two are idlers

Mercury	Venus	Earth	Mars
100 teeth	36 teeth	36 teeth	44 teeth
12 "	18 "	18 "	
12 "	18 "	18 "	
24 "	22 "	36 "	84 teeth
0.24000y	0.61111y	1.00004y	1.90909y
0.24085	0.61521	1.00004	1.88089
−5°27	−3°90	0.00	+2°88

or links, the last is attached to the sleeve which carries the radius-arm of the planet. The resultant lengths of the sidereal revolution periods are given, with the correct values, the error being expressed in terms of the number of degrees before (+) or behind (−) its proper position the planet will be found after one "year" or revolution of the earth. If these errors are within the range to be tolerated for a demonstration instru-

ment to be built at minimum cost, we may consider these trains the ones to be adopted. If not, additional gears might be located, to interpose instead of the idlers, which may increase the accuracy without materially increasing the cost. If standard gears cannot be found, there is always the possibility of having a few cut specially, but this will run the cost up out of all proportion to the gain in accuracy. An error will always remain, of course, so the instrument cannot, without occasional resetting, be used for prediction purposes far in advance, however small the error has been made.

The errors of the above table seem even smaller when we consider that we have used only 14 gears, catalogued at a total cost of $4.03. This figure does not represent the total cost of the orrery. There must be obtained 5 tubes which neatly nest inside each other to permit independent smooth motions. Too, there is the cost of the motor (probably about $10), the driving shaft, spindles for the idler gears, plates to form the framework for the gear box, bushings and separators for the plates and gears, and radius-arms for the planets, suitably attached to the upper ends of the driving sleeves by collars equipped with set-screws (to permit rectification of the instrument for any particular date). The diagram (Figure 1) is only schematic, but should make clear the arrangement of the gears in the gear box; the latter need be only about 2x3x4 inches in size. A suitable motor with which I am familiar can be put in a space 4x5x6 inches in size, perhaps beneath the base of the orrery.

The Sun-Earth-Moon Orrery

This is a more complicated machine, but one which should be particularly interesting and instructive. It will show the rotation of the earth, the revolution of the earth about the sun, the revolution of the moon about the earth, and the regression of the nodes of the moon's orbit. The precession of the earth's axis is not included (it is well demonstrated in other ways, as is well known); instead, the earth's axis is maintained always parallel to itself. Five motions, then, are to be represented. Again there are difficulties of scale; perhaps a distance of 15 to 18 inches from the earth to the sun might be suitable. The distance of the moon from the earth must be decided upon after a decision as to the sizes of the globes of the sun, moon, and earth, and the distance from the earth to the sun. Probably the best arrangement is to put the moon (perhaps a half-inch in diameter) at such a distance from the earth (two inches in diameter) that at the time of an eclipse the tip of the moon's shadow barely reaches the earth, so that a distinct umbral shadow path can be seen on the earth. For this orrery, the sun must certainly be an incandescent bulb, or a smooth spherical globe surrounding a smaller light; it should be larger than the earth, of course.

In this model, the gear trains are carried with the arm which supports the earth in its revolution about the sun (as a matter of fact, the arm consists of the gears and their supports). For this reason (that is, because of the weight), it is probably wise to provide for a wheel at the

end of the arm, to support the arm during its revolution, or a counterbalance at the opposite side of the sun.

The following table exhibits the gear trains used for the four motions

Regression of Moon's nodes	Revolution of Moon about Earth	Alignment of Earth's axis	Rotation of Earth
54	120	18	192
100 - 15	18 - 36	18 - 18	14 - 120
60 - 16	18 - 18	18	18 - 20
20 - 18	18		15 - 18
18 - 18			18 - 36
36			18 - 18
			12
0.054 rev. per year	13.333 rev. per year	1.000 rev. per year	365.714 rev. per year

exclusive of the revolution of the earth about the sun. This latter is accomplished directly by gearing the motor to the arm carrying the rest of the gears; this motion furnishes the power to drive all the other motions. In the above table, the first gear in each column is one which is fixed rigidly to the upright tube which bears the sun at the top. The last gear in each column is attached directly to the shaft or sleeve which furnishes the actual motion involved. In each line of any one column, the gears are on a single shaft, so that as one makes one revolution the other does also. The last row of the table tells us how many cycles of the particular motion are completed each time the earth revolves about the sun once. The true values for these motions are not far from these. For example, the model shows the nodes of the moon's orbit regressing at the rate of $0.054 \times 360°$ or 19°.44 per year; the true value is close to 19°.36. There are 13.369 sidereal months in a year, instead of 13.333. The earth's axis precesses in a period of 25,800 years, instead of remaining parallel to itself. There are 366.256 sidereal days in a sidereal year, instead of 365.714. Certainly these errors are small enough to permit the instrument to be useful in demonstrating some of the difficult topics of the sun-earth-moon system. The gears involved number 34, and are listed at a total cost of $14.65.

Referring to the last column of the table, and to the bottom gear train in Figure 2, we find that the rotation of the earth is accomplished in the following fashion. A spur gear of 192 teeth is attached rigidly to the vertical shaft supporting the sun. Meshed with it is a 14-tooth spur gear, on the same shaft with a 120-tooth spur gear. This shaft is supported by an arm of thin brass which is driven about the vertical base by means of a gear attached to the arm or plate, and meshed directly with the spur gear on the motor shaft. As the motor turns, the arm or plate carrying the train of gears is forced to turn, the 14-tooth gear is forced to roll about the 192-tooth gear, and the 120-tooth gear is forced to turn. The latter meshes with an 18-tooth spur gear, on the same shaft as a 20-tooth spur gear. The latter meshes with a 15-tooth spur gear which is on the same shaft as an 18-tooth miter gear which meshes with the other

of the pair. This latter 18-tooth miter gear is attached to a horizontal shaft which carries the motion out to the bottom of the vertical axis which supports the earth and the moon. There it bears a 36-tooth bevel gear which meshes with an 18-tooth bevel, to translate the motion from horizontal to vertical rotation. At the top of this shaft is an 18-tooth bevel gear which meshes with a 12-tooth spur gear. This last step is the only very tricky one of the whole system; it may require some filing of the teeth of the spur gear to get and maintain a good mesh between the tapered-tooth bevel gear and the straight-tooth spur gear. This is the only departure from standard gears, except perhaps that some of the holes in the gears may need to be reamed out or bushed up, to fit the various spindles and axes.

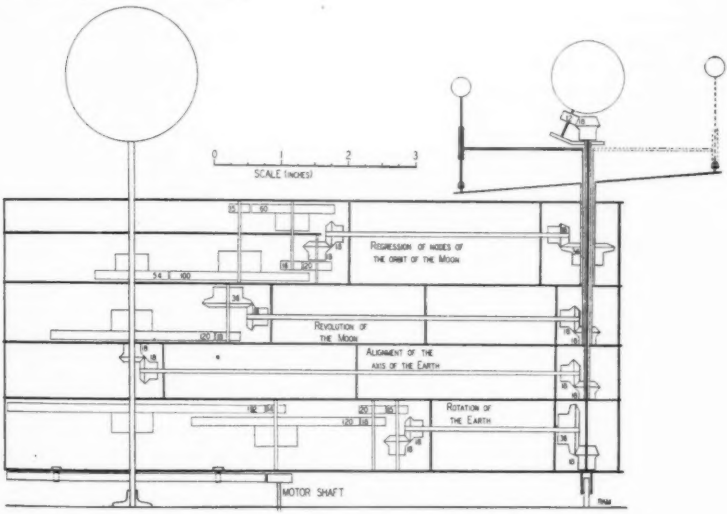

SCALE (INCHES)
REGRESSION OF NODES OF THE ORBIT OF THE MOON
REVOLUTION OF THE MOON
ALIGNMENT OF THE AXIS OF THE EARTH
ROTATION OF THE EARTH
MOTOR SHAFT

FIGURE 2
THE SUN-EARTH-MOON ORRERY

Again a motor is an extra item, as well as the shaft and sleeves, spindles, bushings, separators, and plates to make the main gear box. The motor which I have in mind is one similar to one which I have used successfully for more than a year to drive a refractor used as a guiding instrument for an attached camera of 20 inches focal length. It is quite sturdy, may have its speed altered over a wide range, and can be obtained with driving shaft speeds as low as fractional parts of a revolution per minute. The built-in gear reduction makes it unnecessary to provide additional gears for this purpose. The motor and reduction complete cost in the neighborhood of $10.

The gear box of the orrery need be only about 4x4x20 inches. Some neatness might be accomplished by making the several drive shafts tubes

which nest inside each other, but this will probably not be much of an improvement in operation. Immediately beneath the inclined plane representing the orbital inclination of the moon, a cover of sheet metal or plywood might be placed, to hide the gear box; a large annulus outside this, with a vertical drop all the way round would hide the rest of the machinery except that which is necessary to drive the earth on its axis and the moon in its revolution in the proper plane. The whole instrument might thus be made quite neat and clean in appearance, unless one wishes purposely to leave the gear trains exposed, as they are in almost all old orreries, probably to show off the skill of the designer and mechanic.

If someone with more time and money immediately at his disposal has a try at either of these two machines before I get to them, I hope he will give me the benefit of his experience. Although equipped with but meager mechanical skill and intuition, I believe that they will work, cost little, and be satisfactory in the demonstration of many fundamental phenomena.

WILSON COLLEGE, CHAMBERSBURG, PENNSYLVANIA.

Planet Notes for September and October, 1938

By R. S. ZUG

Note: Greenwich Civil Time is employed, unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours; Central Standard Time, 6 hours; etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The positions of the sun for September 1 and September 30, respectively, are: $\alpha = 10^h\,38^m.3$, $\delta = +8°\,36'.6$; $\alpha = 12^h\,22^m.7$, $\delta = -2°\,27'.1$. The corresponding positions for October 1 and October 31, respectively, are: $\alpha = 12^h\,26^m.3$, $\delta = -2°\,50'.5$; $\alpha = 14^h\,18^m.3$, $\delta = -13°\,49'.5$. The sun is in the constellation Leo until September 16, when it enters the constellation Virgo. It then continues in Virgo until October 31, on which day it enters the constellation Libra. The sun reaches the autumnal equinox on September 23, $17^h\,0^m$, ushering in the season of autumn. At this time the sun's southerly motion is the most rapid of the year, 23'.4 per day.

Moon. Phenomena of the moon will occur as follows:

			h	m
First Quarter	September	1	17	28
Full Moon		9	20	8
Last Quarter		17	3	12
New Moon		23	20	34
First Quarter	October	1	11	45
Full Moon		9	9	37
Last Quarter		16	9	24
New Moon		23	8	42
First Quarter		31	7	45

		h	m
Apogee	September	4	17
Perigee		20	12
Apogee	October	2	11
Perigee		16	8
Apogee		30	7

Mercury. September 1 finds Mercury a morning star, but quite close to the sun. The planet reaches its greatest western elongation, 17° 54′, on September 13, 21^h. For a few days before and after this date the planet should be a conspicuous object in the morning sky. On the morning of September 14, star gazers will find Mercury 17° above the horizon just before sunrise, and almost due east, an object of stellar magnitude 0.0. The 1.3 magnitude star, Regulus (α Leonis), will be situated about 4° above Mercury, while the planet Mars will be a degree below. This elongation of Mercury provides the best opportunity of the year for locating the elusive planet in the morning sky.

Interesting configurations of Mercury, Mars, and Regulus may be viewed for a number of days prior to, and following, the date of greatest western elongation. It may be possible to locate the two planets as early as September 6, by means of the straight line configuration which they will form with the star Regulus on the morning of that day. Mars will then be found three-fourths of a degree to the north of Regulus, and Mercury a degree and a half to the south. The two planets will then move eastward from Regulus, and the angular distance between them will decrease until September 16, 15^h, when they will be separated by only 10′ of arc. On the morning of either the 16th or the 17th, therefore, early risers should find the two planets in close proximity, below Regulus, with Mercury the brighter planet.

Mercury again reaches superior conjunction with the sun on October 10.

Venus. Venus reaches a greatest eastern elongation from the sun of 46° 19′ on September 11. The planet will be a very brilliant evening star during September and October, but because of its southerly declination it will set less than an hour and a half after the sun during these months. Greatest brilliancy is attained on October 16, when the stellar magnitude will be —4.3. Data of interest to observers are the following:

Date 1938	Stellar Magnitude	% of Disk Seen Illuminated	Angular Diameter	Distance from Earth, miles
Sept. 1	—3.9	53	22″.3	70,189,000
Oct. 1	—4.2	36	32.2	48,329,000
Nov. 1	—4.1	10	52.7	29,678,000

Mars. Mars is now a morning star, gradually drawing farther from the sun. It will be poorly placed for telescopic observation during September and October.

Jupiter. Jupiter will be situated in the eastern part of the constellation Capricornus during the months of September and October. The apparent motion of the planet among the stars is retrograde until October 19, after which it is direct. Its brilliancy is slowly diminishing, the stellar magnitude being —2.4 on September 1 and —2.1 on November 1.

Saturn. Saturn is in slow retrograde motion through the southern portion of the constellation Pisces. Opposition with the sun occurs on October 8, 13^h, at which time the stellar magnitude is +0.4. The ring system, the southern surface of which is now visible, is becoming more discernable. The minor axis of the outer ellipse of the outer ring is 7″.3 at opposition, the major axis at the same time being 44″.6.

Uranus. Uranus is in slow retrograde motion in the constellation Aries. Positions of Uranus in right ascension and declination are listed below:

Date 1938	α h m	δ ° ′
Sept. 1	3 1.7	+16 47
Oct. 1	2 59.6	+16 37
Nov. 1	2 55.1	+16 18

The center of the moon's disk passes 32′ to the north of Uranus (as seen geocentrically) on September 14, $12^h\ 48^m$, and again 29′ to the north on October 11, $17^h\ 41^m$.

Neptune. Neptune is in conjunction with the sun on September 14. On October 12, 9^h, the planet Mars comes into conjunction with Neptune, the angular separation at the time being 5′ of arc. Neptune will be situated to the south of Mars, which latter planet will be moving in a southeasterly direction at the rate of about 1′.5 an hour.

Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Occultations Visible in Longitude +72° 30′, Latitude +42° 30′.

Date 1938	Star	Mag.	IMMERSION Greenwich C.T. h m	IMMERSION a m	IMMERSION b m	IMMERSION Angle E from N °	EMERSION Greenwich C.T. h m	EMERSION a m	EMERSION b m	EMERSION Angle E from N °
Sept. 3	21 Sgr	5.0	21 25.6	—1.5	+1.5	81	22 50.5	—1.8	+0.6	274
4	*d* Sgr	5.0	23 3.7	—1.8	+0.2	120	0 10.0	—1.8	+1.9	218
5	45 Sgr	6.0	2 32.9	—0.8	+1.5	23	3 30.0	—2.4	—2.4	299
8	c^1 Cap	5.3	1 8.3	—1.7	+1.4	78	2 30.1	—1.6	+1.4	231
13	12 H.Ari	6.3	9 52.3	—1.5	—2.5	118	10 46.7	—1.1	+1.4	210
14	124 B.Ari	6.4	7 5.2	—1.8	+0.9	80	8 26.0	—1.8	+1.0	242
14	Uranus	6.0	13 35.7	—0.2	—1.5	100	14 31.4	—0.1	—0.7	248
17	BD+19°1110	6.0	8 27.5	—1.5	+0.8	96	9 44.4	—1.7	+0.7	264
17	57 Ori	5.9	9 57.8	—1.9	—0.9	120	11 10.7	—2.0	+0.9	247
20	A^2 Cnc	5.7	7 5.8	0.0	0.0	132	7 52.5	0.0	+1.8	251
30	ξ Oph	4.5	0 49.1	—1.0	—0.9	77	2 1.2	—0.7	—1.4	268
Oct. 2	171 B.Sgr	6.1	1 9.7	—2.6	—2.5	126	1 57.9	—0.1	+1.6	199
2	173 B.Sgr	6.3	1 3.6	—1.7	—0.8	88	2 20.9	—0.8	—0.3	236
6	6 G.Psc	6.2	22 14.9	—0.6	+1.9	65	23 24.6	—1.0	+1.7	248
7	BD+1°4773	6.4	23 42.1	—1.0	+1.5	89	0 46.0	—0.8	+2.2	218
8	22 Psc	5.8	2 13.3	—0.9	+2.5	26	3 20.7	—2.3	—0.1	275
11	29 Ari	6.1	4 36.8	..	..	133	5 11.3	..	..	185
13	234 B.Tau	6.0	2 39.2	..	..	160	2 48.0	..	..	177
17	84 B.Cnc	6.4	7 50.7	—0.9	+2.5	65	8 43.8	—1.2	—1.2	325
18	ω Leo	5.5	7 24.2	—0.4	+1.1	98	8 26.0	—0.8	+0.4	297
30	16 B.Cap	6.2	23 55.3	—1.0	+1.0	34	1 5.8	—1.9	—1.6	278
31	β Cap	3.2	0 2.7	—1.1	+0.8	40	1 16.2	—1.7	—1.4	272

Occultations Visible in Longitude +91° 0′, Latitude +40° 0′.

Sept.	5	45	Sgr	6.0	2	14.3	..	..	356	2	33.7	..	..	333
	8	c^1	Cap	5.3	0	40.9	—1.0	+1.8	75	1	56.6	—1.4	+1.7	243
	13	12	H.[1]Ari	6.3	9	18.1	—2.5	—1.7	114	10	18.2	—1.4	+2.5	206
	14	124	B.Ari	6.4	6	34.8	—1.1	+1.8	65	7	50.7	—1.6	+1.2	254
	14		Uranus	6.0	13	33.2	—0.6	—2.5	122	14	24.2	—0.8	+0.4	224
	17	BD+19°1110		6.0	8	4.6	—0.8	+1.3	88	9	13.4	—1.2	+1.1	266
	17	57	Ori	5.9	9	25.8	—1.7	—0.2	120	10	32.0	—1.5	+2.0	238
	19	1	Cnc	6.0	10	33.4	—0.8	+4.2	43	11	9.3	—1.4	—2.9	341
	20	60	Cnc	5.7	10	56.2	—0.9	+0.1	123	12	1.7	—1.2	+1.0	270
	30		ξ Oph	4.5	0	24.0	—1.7	—0.1	66	1	44.9	—1.6	—1.6	282
Oct.	1	16	Sgr	6.0	2	17.3	—1.2	—0.3	63	3	32.0	—1.0	—1.4	270
	2	171	B.Sgr	6.1	0	24.4	—2.6	—0.6	107	1	41.1	—1.4	+0.9	221
	2	173	B.Sgr	6.3	0	26.1	—2.2	+0.4	75	1	57.9	—1.9	—0.3	253
	2	187	B.Sgr	6.4	3	26.4	—0.9	—0.3	61	4	38.8	—0.8	—1.2	263
	6	51	Aqu	5.8	7	45.9	—0.1	+1.9	14	8	26.6	—0.7	—3.0	296
	7	BD+1°4773		6.4	23	27.5	—0.3	+1.5	84	0	27.3	—0.5	+2.0	229
	8	22	Psc	5.8	1	56.7	..	..	0	2	32.7	..	..	305
	11	29	Ari	6.1	3	57.5	—1.5	+0.7	107	4	52.9	—0.6	+2.8	210
	13	234	B.Tau	6.0	2	24.4	—0.2	0.0	132	2	56.7	+0.6	+2.6	208
	13		ε Tau	3.6	3	56.9	—1.2	—0.7	140	4	25.8	+0.6	+3.8	198
	17	84	B.Cnc	6.4	7	36.4	—0.2	+2.1	67	8	26.7	—0.8	—0.5	317
	18		ω Leo	5.5	7	19.7	+0.1	+0.9	98	8	15.2	—0.2	+0.6	292
	29	130	B.Sgr	6.6	1	21.3	—1.7	—2.0	113	2	18.6	—0.1	+0.6	214
	30	16	B.Cap	6.2	23	31.2	..	..	11	0	22.7	..	..	304
	30		β Cap	3.2	23	36.7	—1.1	+2.5	18	0	37.6	—3.1	—1.7	297

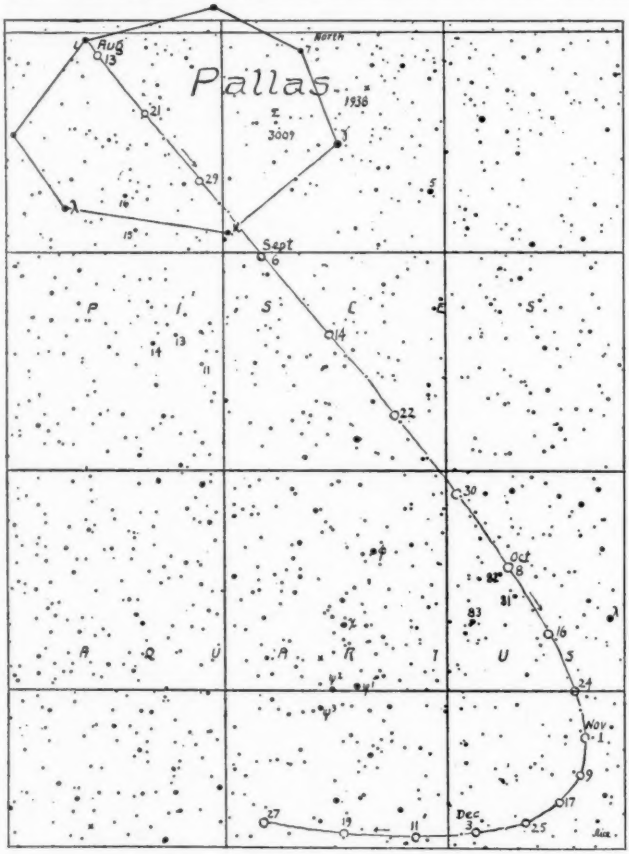
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′.

Sept.	5	45	Sgr	6.0	0	57.9	..	..	16	1	30.2	..	..	330
	6	16	B.Cap	6.2	8	50.3	..	..	354	9	13.0	..	..	317
	6		β Cap	3.2	8	51.5	+0.6	+3.0	6	9	26.7	—2.0	—3.9	306
	7		ν Aqu	4.5	9	11.8	—0.4	+1.3	27	10	9.6	—1.2	—1.8	280
	13	12	H.[1]Ari	6.3	8	10.9	—1.7	+1.2	83	9	27.1	—1.4	+2.0	227
	14	124	B.Ari	6.4	6	14.2	+0.1	+2.3	39	7	6.8	—0.9	+0.8	282
	17	BD+19°1110		6.0	7	52.6	+0.3	+1.5	70	8	46.3	—0.4	+0.8	282
	17	57	Ori	5.9	8	54.6	—0.5	+0.8	104	9	53.5	—0.5	+1.7	249
	17	64	Ori	5.2	13	25.5	—2.1	—1.6	129	14	37.1	—2.4	+1.3	242
	19	1	Cnc	6.0	10	16.6	+0.6	+4.0	35	10	42.7	—1.0	—2.3	341
	20	60	Cnc	5.7	10	42.7	—0.1	+0.1	125	11	34.8	—0.2	+1.4	261
	20		α Cnc	4.3	12	3.1	..	..	22	12	11.2	..	..	6
	28		κ Lib	5.0	3	35.7	—0.9	—1.6	110	4	37.9	—0.1	—0.8	253
Oct.	1	15	Sgr	5.4	1	22.5	..	..	131	2	23.6	..	..	211
	1	16	Sgr	6.0	1	24.1	—2.2	+1.5	45	2	44.0	—2.8	—1.5	296
	1	173	B.Sgr	6.3	23	21.3	—1.7	+1.5	80	0	51.0	—2.2	+0.7	266
	2	187	B.Sgr	6.4	2	44.1	—1.7	+1.8	33	3	56.7	—2.9	—1.8	293
	4	84	B.Cap	6.0	7	52.7	+0.4	+2.6	8	8	29.8	—1.4	—3.5	302
	11	29	Ari	6.1	3	33.5	—0.1	+1.3	83	4	30.0	—0.2	+1.8	237
	11	124	B.Ari	6.4	15	2.9	—0.2	—0.8	80	15	59.1	+0.2	—1.0	268
	12	26	B.Tau	6.4	5	35.9	—1.1	+0.1	121	6	18.6	0.0	+3.0	205
	17	A^1	Cnc	5.7	11	56.5	—1.5	+1.8	76	13	1.1	—1.5	—1.5	320
	17	A^2	Cnc	5.7	14	23.2	—1.8	—1.2	124	15	44.5	—2.0	—0.9	284
	28	16	G.Sgr	6.5	3	57.1	—0.1	+0.4	41	4	49.6	—0.7	—2.2	294
	29	130	B.Sgr	6.6	0	20.0	—2.5	0.0	88	1	51.9	—1.9	+0.2	243
	29	BD—19°5182		6.4	3	16.9	—0.6	+0.8	37	4	18.5	—1.4	—2.1	288
	31	31	ν Aqu	4.5	23	46.2	..	..	358	0	14.4	..	..	322

Asteroid Notes

By HUGH S. RICE

Ceres is visible in the eastern sky very late at night during the summer, but is not as convenient for observation now as it will be later in the year. On August 9 it is 1° southeast of ξ Tauri. On August 31 it passes just south of 30 Tauri; on September 23 (soon after which it begins to retrograde) it is 1½° southwest of λ Tauri. The magnitude of Ceres ranges from 8.8 to 7.9 during the period.



Pallas for the rest of the year is shown on the accompanying chart. It is the best asteroid for observation with a small telescope during the last half of this summer. The positions shown on the chart are for 7 P.M. E.S.T. of the dates marked. The magnitude range is from 9.0, on August 1, to 8.6, on October 1, and 9.3, at the end of the year. This apparent path in Pisces and Aquarius is

thus good for a large number of weeks. In August, Pallas will be seen to traverse the "circlet of Pisces," which is outlined on the chart with lines, for easy identification; this famous circlet is a naked-eye configuration, directly south of the great square of Pegasus. Opposition takes place on September 11.

Juno is the faintest of the big four of the minor planets, for its magnitude averages about 10.5 during this period. On August 1 it is a bit over 3° nearly east of ϵ Ophiuchi. On September 28 it is immediately north of ρ Ophiuchi.

Vesta is still good on the chart published in the preceding issue of this magazine. It will thus be seen that all of the big four asteroids are observable this summer (which is not always true) so that telescope users will have a fairly unusual opportunity. The chart mentioned is good until the end of August. After that time Vesta progresses to a point in the Milky Way, 7½° northeast of Antares and very near the ecliptic, at the end of September. The magnitude ranges from 6.6, on August 1, to 7.3, near the end of September. At the latter date it will be fairly low in the western sky in the early evening.

Two of the asteroids known to approach the earth much nearer than Eros may this summer be in a position to be observed by very large telescopes or by photography. Amor of magnitude 20 comes to opposition on September 30, near the Cetus-Pisces border, according to computations by the Rechen-Institut; and Adonis has had its place computed by Cunningham for July. Its place is in Gemini, and magnitude about 19.

Probably the three next best asteroids, besides the first four, for observation with small telescopes are the ones whose places we give below. The ephemerides were, as usual, computed by the Rechen-Institut at Berlin-Dahlem, Germany.

EPHEMERIDES OF ASTEROIDS. FOR 0^h U.T. EQUINOX OF 1950.

216 KLEOPATRA 8^M.6

		α h m	δ ° ′
Sept.	3	0 0.6	+16 40
	11	23 56.6	15 51
	19	23 51.8	14 41
	27	23 46.7	13 14
Oct.	5	23 41.9	11 34
	13	23 38.1	+ 9 50

20 MASSALIA 9^M.1

		α h m	δ ° ′
Sept.	11	0 34.3	+ 4 15
	19	0 28.1	3 34
	27	0 21.0	2 46
Oct.	5	0 13.7	1 57
	13	0 6.7	1 8
	21	0 0.7	+ 0 25

30 URANIA 9^M.2

		α h m	δ ° ′
Sept.	11	0 36.9	+ 7 16
	19	0 30.9	6 50
	27	0 23.9	6 15
Oct.	5	0 16.5	5 35
	13	0 9.7	4 54
	21	0 4.0	+ 4 16

Hayden Planetarium, American Museum of Natural History,
New York City, July 21, 1938.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

As often happens these Notes will be divided into three sections which will be taken up in succession. First I should like to mention a most interesting paper which has just appeared: "How larger bodies may be built up out of small particles in interstellar space" by Alex Corlin of Lund, which is reprinted from *'Zeitschrift für Astrophysik,'* 15 Band, 4 Heft, as *'Meddelande från Lunds Observatorium, Nr. 148.'* It is 24 pages in length and fortunately in English. The writer of this paper is totally dissatisfied with all older theories of the origin of meteors and meteorites. He gives a very fair, if critical, discussion of these previous theories and the reasons why he disagrees. He then proceeds to develop his own theory. To discuss his work intelligently would require a good knowledge of modern mathematical physics, and, after some hesitation, it seems to me the wisest thing is simply to quote a large part of Corlin's own résumé. This will at least permit those readers who would like to follow the matter further to see his line of argument and to decide as to whether they are competent to understand it. I do not hesitate to say that my own knowledge of the actions, real or supposed, of cosmic rays and other charged particles in space is too limited to pass judgment upon this new theory. But I hope that this note will serve to call attention of specialists in these lines of research to this paper so that we may have their opinions. The following is directly quoted: " . . In part II it is shown that the cosmic ray bursts (Hoffmannsche Stösse) released in interstellar bodies charge up these bodies positively by sending out into space large numbers of secondary electrons instantaneously. This charge is afterwards neutralized by free interstellar electrons; the time of the charge due to a single burst is $37/\sqrt{R}$ hours, where R is the radius of the body in cm. The frequency of bursts is 5.26 cm^{-2} $year^{-1}$ and increases with the surface of the body, so that bodies with a radius larger than 2.34 cm remain permanently charged and cannot be attracted by a meteorite. This limiting size is just the size of the largest chrondules ever found in meteorites. The collection of small neutral or negatively charged particles by a meteorite through electrostatic attraction occurs in proportion to the mass of a meteorite in the power 2/3. When the data of F. Panath as to the ages and average sizes of the meteorites as well as of his specimens are inserted in this formula, they directly lead to the average mass of the comets in 4.10^{12} years, the age of the galaxy according to the long time scale. The comets are here assumed to be of interstellar origin and braked by the interstellar resisting matter so as to get parabolic motion with respect to the sun as is further treated in another paper. An important result by B. Jung that interstellar particles get a positive charge because of the photoelectric effect due to starlight and thus repel each other is considered and explained as an average condition, from which exceptions occur when the ratio of ionizating quanta and free electrons is 9.3 times less than the average value of this ratio. Only one out of 62,800 bursts needs to catch a milligram particle in order to maintain the building process."

Next of interest to our members are some details of the principal showers which have appeared in recent months. Observations from two of our very active foreign members will be mentioned, as well as of several in this country. First,

Prof. Mohd. A. R. Kahn of Begumpet, India, reports for 1937 Nov. 11, 21:00 to 22:00 U.T., observing to E and SE, sky clear, that he saw 27 meteors all of magnitude 2 or brighter, some with long white streaks. No radiant was mentioned but Leonids have been seen that early. On Dec. 12, 20:00 to 21:30 U.T., sky clear last hour, 22 Geminids from a radiant at RA = 108°, Decl. = +33°, were observed, 3 brighter than —1; also 21 sporadic meteors. On Dec. 13, 19:15 to 20:30 U.T., clouds a third of the time, 16 Geminids and 13 sporadic meteors were seen; three Geminids were of —1 or —2 magn. 1938 Jan. 2, 22:00 to 24:00 U.T., 12 Quadrantids and 27 sporadic meteors, 3 brighter than —1; but streaks not enduring. From these notes it will be seen that the meteor rates were quite high on all the four shower nights mentioned. From E. Loreta of Bologna, Italy, we have as follows:

1938			Min.	Lyrids	Sporadic
April 19	9:30	to 10:55	75	4	6
21-22	10:00	12:55	150	18	16
23-24	9:30	13:55	200	8	21
				Aquarids	
April 30-May 1	14:00	14:55	50	0	3
2- 3	14:00	14:55	50	5	2
7- 8	14:00	14:55	50	5	6
8- 9	13:00	14:55	100	7	12

It is inferred that the periods of observation were clear, or otherwise notes would be added as to clouds. The Lyrid maximum was evidently on April 21-22. The times used are G.M.T., changed by me to noon to noon reckoning, as we always desire to use the latter in our work. The η Aquarids were in small numbers, but we are now 28 years past perihelion for Halley's comet. Coming to this country F. W. Smith, at Vineland, N. J., was able to observe once in each of these epochs. On April 23-24, 9^h to 10^h E.S.T., F = 1.0, 3 sporadic meteors; on May 6-7, 13:30 to 14:30, F = 1.0, one sporadic only. It is plain that meteor rates are very different at different places on the Earth, even for the same or approximately the same dates.

W. R. Stone of San Diego, Calif., observed on 1938 April 21-22 from 10:30 to 14:30 P.S.T., sky clear, Moon up during last hour; 21 meteors, 2 of 1 magn., all plotted, at least ⅝ Lyrids. On May 3-4, 12:30 to 16:00, clear, 6 Aquarids, one sporadic; May 4-5, 13:00 to 16:00, clear, 2 sporadic only. The Louisville Astronomical Society had a group out, 10 observers in all, on April 22-23. Eight observed from 11^h to 13^h; they averaged 21 meteors for the two hours, rate 10.5 evidently. The observer with minimum number saw 12, with maximum saw 29. These were counts, only a few being plotted, so I cannot give relative numbers of Lyrids and sporadic meteors. Gordon Green of Pittsfield, Mass., on 1937 Nov. 10-11, from 12:15 to 13:45 E.S.T., F = 1.0, saw 14 meteors, plotted 5, says none of the 14 was a Leonid. On 1938 April 19, 9:33 to 11:47, F = 0.9; 2 Lyrids and 5 sporadic; the 2 Lyrid tracks cross at RA = 274°, Decl. = +36°. Finally, H. Stackpole, San Jose, Calif., on 1937 Dec. 12-13 from 9:15 to 11:28 P.S.T., F = 0.7, saw 27 meteors, the majority being Geminids, and most of the 27 were plotted. Moon about 0.6.

There is little doubt but that others of our members have made observations on the showers of the first part of 1938 and have not yet reported them. Incidentally in these Notes of February, other observations on the Quadrantids were published. However, there is still a sad lack of activity in fully 70 per cent of our membership. It is hoped that the warm nights of summer will have a rejuv-

enating effect upon this majority!

The third part of the Notes consists of the results on a recent fireball, issued as a joint paper.

The New York Fireball of 1938 April 12

By CLAUDE H. SMITH AND C. P. OLIVIER

At 7:25 E.S.T., in the evening of April 12, a brilliant fireball crossed central New York in a west-north-west direction, ending near Rochester. C. H. Smith of Waterloo, N. Y., Regional Director for the A.M.S., at once had notices put into many local papers asking for observations. In response, about 60 reports came in, a few of which were checked by personal interviews, while many were followed up, as usual, by the sending of our standard fireball questionnaires. As a result of this campaign, the following data were derived, the greatest uncertainty being as to the position of the beginning point. The solution, in general, suffers from no observer referring either end of the path to the stars; only one used the Moon for a reference point even though it was most obviously a good one for the beginning point. Hence we have to depend upon "dead reckonings" with their inevitable uncertainties.

Began over	$\lambda = 75°\ 40'$ W	$\phi = 42°\ 33'$ N
Ended over	$\lambda = 77°\ 27'$	$\phi = 43°\ 03'$
Sidereal time at end point		129°
Beginning height	77.3 km	± 24.5 km
End height	16.9	± 3.8
Length of path	176	
Projected length of path	165	
Observed geocentric velocity.....	22 km/sec for 8.0 sec; 28 km/sec for 6.3 sec	
Radiant.....	Azimuth = 291°; altitude = 20°	
	$\alpha = 188°$;	$\delta = -2°$

Due to the large probable error of the beginning point, which makes the radiant rather rough, it was not deemed wise to compute an orbit. We have 27 estimates of duration ranging from 1 to 30 seconds, there being 3 of the latter, the next longest being 15 sec. The mean of all 27 gives 8.0 sec; leaving out those of 2 sec. and less (obviously too small) and the three of 30 sec., the mean of the remaining 19 is 6.3 sec. It is questionable which is more correct, so velocities based upon each are given above for what they are worth. The usual variety of colors is reported, but blue, white, and green are in great prepondenence; we may conclude that the fireball was bluish. No train was left behind for any appreciable time. The range in apparent diameter is from 1/20 to equal to full Moon's diameter, but a very good average would be about one-fourth to one-third. Hence the object certainly seemed to give a discernable disc. Only 2 reports say a slight sound was heard from one-half to one minute later; 4 reports mention a "hissing" or "swishing sound" simultaneously with seeing it. Internal evidence would dismiss all but one of the latter as being due to what observers *thought* afterwards they should have heard and the impressions may be considered as illusory. The one exception is specific in saying attention was first called to the object by a sort of "whizz." Like sounds produced by aurorae, as sometimes reported, this phenomenon is still controversial, though it is evident it is not a "sound" effect in the usual sense that the word is used, even if it eventually proves to be real. There was no explosion, no final brightening, and despite the low altitude it is extremely doubtful therefore if any fragments fell as meteorites.

The gathering of the data and the working out of the preliminary solution

are due to C. H. Smith, the final solution is due to C. P. Olivier. Far the greater part of the work was done by the former. We are under great obligation to the press for cordial co-operation, and to the observers for their willingness and trouble in reporting.

Flower Observatory of the University of Pennsylvania,
Upper Darby, Pennsylvania, 1938 June 13.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California at Los Angeles

President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver
Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California at Los Angeles

On the Meteoritic Origin of the Black Stone of the Ka'bah

By MOHD. A. R. KHAN,
Begumpet, Deccan, N. S. R., India

Abstract.—Various descriptions and a history of the Black Stone of the Ka'bah, and speculations as to its nature and origin, are included in this paper. In the opinion of the writer, many people would prefer to assume that the tradition about the Stone's having been brought by the Angel Gabriel and given to Abraham and Ishmael for setting in a wall of the Ka'bah, arose out of an attempt to explain its witnessed fall as an aërolite, which may have happened not long before the first recorded rebuilding of the Ka'bah.

Conflicting reports were published about the origin of the Black Stone of the Ka'bah in the nineteenth and twentieth centuries by European writers on Arabia, some of whom had the privilege of actually (though hurriedly) examining the Stone while visiting Al-Makkah (Mecca), disguised as pilgrims, while others based their conjectures on the accounts published by these travelers or on writings of older Arab historians. As may be expected, early Arab writers attribute to the Black Stone a "celestial" origin, as having been brought by the Angel Gabriel and fixed by Abraham and Ishmael in the northeast corner of the Ka'bah, when it was rebuilt after the Deluge—a modest, roof-less building, cubical in shape (as the name signifies). At the birth of Islam it was again rebuilt from the wreckage of some Greek ships, picked up on the shore of the Red Sea (Al-Azraqī, "Akhbar Makkah," ed. Wüstenfeld, Leipzig, 1858, pp. 104-7). About the origin of the Black Stone, Azraqī (*loc. cit.*, p. 10) writes that it was originally one of the stars of Paradise and was then (of the color of) a bright ruby. Folklore was mixed up with fact when some credulous pilgrims believed in the past (and may believe possibly to the present day) that the Stone was a transparent crystal when first brought from heaven, but gradually lost its transparency and assumed its present black color and opacity as a cumulative effect of sins committed in successive generations! On account of the sanctity of the Ka'bah from time immemorial and the association of the Black Stone with the ceremonials of Hajj (the annual Muslim pilgrimage to Makkah), it is by no means easy for even a Muslim scientist to

photograph the Stone, much less examine it under the microscope or analyze a piece of it chemically. The accompanying figure is a photograph of the clear il-

FIGURE 1
SIDE AND FRONT VIEWS OF THE BLACK STONE
OF THE KA'BAH
(For reference, see the paper.)

lustration published in Sir William Muir's "The Life of Mahomet" (Smith Elder & Co., 15, Waterloo Place, London, 1894), which is reproduced presumably from an engraving by "Ali Bey" (the Spanish traveler and geologist, Domingo Belia Y. Leblich), as it agrees exactly with the rather dim copy facing p. 78 of Professor D. S. Margoliouth's book "Mohammad" ("Heroes of the Nations Series," published by G. P. Putnam's Sons), taken from "Ali Bey's" "Travels" (London, 1816).

Though held in reverence from the earliest times down to the present, the Stone had a very checkered history during the civil wars of the Umayyad and 'Abbasid empires. The first injury done to it was when Al-Husayn ibn-Numayr al-Sukūni, chief officer in charge of the Syrian army from Damascus, beseiged Makkah, where 'Abdullāh ibn-al-Zubayr had taken refuge, after his defeat in the struggle for the Caliphate with Yazīd, son of Mu'āwiyah. Ibn-Numayr's catapults rained stones onto the holy mosk of Makkah, and the conflict became so fierce that the Ka'bah itself caught fire and the Black Stone was split into three pieces (Tabarī, Vol. II, p. 427). Meanwhile, Yazīd died, and the Syrian army, having raised the siege of Makkah, 'Abdullāh ibn-al-Zubayr rebuilt the Ka'bah and had the broken pieces of the Black Stone joined together in a silver framework and placed in the old northeast corner (about 683 A.D.).

The second injury which the Stone was destined to receive occurred in the year 930 A.D., in the reign of the 'Abbasid Caliph Al-Muqtadir, when Abu Tāhir Sulaymān, the Qarmatian chief, having laid waste most of lower Al-'Iraq, cut the pilgrim routes and seized Makkah. A drunken Qarmatian soldier entered the circuit border of the Ka'bah, seated on horseback, and, dealing a heavy blow with a hammer, knocked the Stone down from its setting and took it away (Ibn-Taghrī Birdī, Vol. II, p. 237, Leiden, 1857). For over twenty years the Stone remained with the Qarmatians. It was restored to the Ka'bah in 951 A.D. by order of the Fatimid Caliph al-Mansūr (Baghdādī, ed. Hitti, pp. 176-7; Ibn-al-A-thīr, Vol. VIII, pp. 153-4).

Ibn-Taghrī Birdī (*loc. cit.*, pp. 327 and 331) gives the following details: "In 339 A.H. [950 A.D.], the Qarmatians sent the Black Stone to Caliph Mutī' through Muhammad bin-Bashīr. Before this they refused an offer of 50,000 dinars made

by the Amīr-ul-Umara', Bajkam, for its delivery, saying that they would return the Stone only when ordered by the authority that enjoined upon them to remove it. And when they delivered it to Caliph Mutī', they said they were acting under instructions from that same authority. According to Musabbihī, Sanbar bin-al-Hasan, the Qarmatian, accompanied by the Amīr of Makkah, brought the [broken] Stone to the Ka'bah, put its pieces together with the help of silver lining, and fixed the framework in mortar in a corner of the wall of the Ka'bah. In 340 A.H. [951 A.D.], the Stone was again taken out of its setting and refixed in a silver frame to present the same appearance as in the days of 'Abdullāh-ibn-al-Zubayr."

The following description of the Stone, with other details, from "Ali Bey's" "Travels" (previously cited), quoted by R. H. Kiernan in "The Unveiling of Arabia" (George Harrap, 1937, pp. 109-11), throws light on the views then held with regard to its origin:

"As accepted by the Royal Geographical Society and the British War Office, Makkah [Mecca] has latitude 21° 25′ 18″ N. and longitude 39° 49′ 41″ E.

"The 'Temple' of Makkah comprises the House of God Beit Allāh or Al-Ka'bah; the Well Zemzem, Bir Zimzem; the 'Cobba' or place of Abraham, Maqām Ibrahīm; the places of the four Orthodox rites; Maqām Hanīfah, *etc.* . . The Black Stone (Hajar Aswad) is raised 42 inches above the surface and is bordered all round with a large plate of silver about a foot broad. The part of the Stone that is not covered by the silver is almost a semicircle, 6 inches in height, by 8 inches, 6 lines [in] diameter at its base. We believe that this miraculous Stone was a transparent hyacinth brought from heaven to Abraham by the Angel Gabriel as a pledge of his 'divinity'[?], and, being touched by an impious woman, became black and opaque!

"This Stone is a fragment of volcanic basalt which is sprinkled throughout its composition with small, pointed crystals and 'varied' with feldspar, upon a dark background like coal, except one of its protuberances, which is a little reddish.

"The continual kisses and touchings of the faithful have worn the surface uneven, so that it now has a 'muscular' appearance. It has 15 'muscles' and one deep hollow. Upon comparing the borders of the Stone that are covered and secured by the silver with the uncovered part, I found [that] the latter [had] lost nearly 12 lines of its thickness; from whence we may infer that if the Stone was smooth and even in the time of the Prophet, it has lost a line during each succeeding age."

Evidently "Ali Bey," at the time of writing this account, was unaware of the damages done to the Stone by the Syrians and Qarmatians.

A number of European writers of the last century were of the opinion that the Black Stone was a piece of lava; *e.g.*, (*a*) Sprenger, in "Das Leben und die Lehre des Muhammad II," p. 341, thought it was lava containing white and yellow particles; (*b*) Sir Richard F. Burton in his "Personal Narrative of a Pilgrimage to Al-Madīna and Mecca" (Memorial Edition, Vol. II, 1893, pp. 300-3), writes as follows ("Appendix II"):

"At the northeast corner of the Ka'bah, near the door, is the famous Black Stone;* it forms a part of the sharp angle of the building,† at four or five feet

*A footnote (presumably by the editor, Lady Isabel Burton, adds: ". . . *It appeared to me* [*to be*] *a common aërolite, covered with a thick, slaggy coating, glossy and pitch-like, worn and polished.*"

†Another footnote describes its appearance in profile thus: "The Hajar [Stone] has suffered from the iconoclastic principles of Islām, having once narrowly escaped destruction by order of Al-Hākim of Egypt. In these days the metal rim serves as a protection as well as an ornament."

above the ground. It is an irregular oval about seven inches in diameter, with an undulating surface, composed of about a dozen smaller stones of different sizes and shapes, well joined together with a small quantity of cement, and, perfectly well smoothed, it looks as if the whole had been broken into many pieces by a violent blow, and then united again. It is very difficult to determine accurately the quality of the Stone which has been worn to its present surface by the million [millions of] touches and kisses it has received. It appeared to me like a lava containing several small extraneous particles of a whitish and of a yellowish substance. Its color is now a deep reddish-brown, approaching to black. It is surrounded on all sides by a border composed of a substance which I took to be a close cement of pitch and gravel of a similar, but not quite the same, brownish color. This border serves to support its detached pieces; it is two or three inches in breadth and rises a little above the surface of the Stone. Both the border and the Stone itself are encircled by a silver band, broader below than above, and the two sides, with a considerable swelling below, [look?] as if a part of the Stone were hidden under it. The lower part of the border is studded with silver nails."

(*c*) Burkhardt, in his "Voyages en Arabie," 1935, Vol. I, p. 182, expresses his view in favor of the lava origin, while (*d*) Sir W. Muir (*loc. cit.*, p. 27) writes, ". . . This Stone, which is semicircular, measures some six inches in height and eight in breadth; it is of a reddish-black color, and, notwithstanding the polish impressed by myriads of kisses, bears to the present day in its undulating surface, marks of a volcanic origin."

These accounts suggest (as has been remarked by Professor Margoliouth in a recent communication to the present writer) that plagiarism was a common practice. Concerning the notion about the meteoritic origin of the Stone, he thinks that this is based on the tradition that it was brought by the Angel Gabriel (Qutb-al-dīn, died 990 A.H., ed. Wüstenfeld, p. 30), and suggests that "perhaps some guidance may be got from the fact that it was split by the heat when the Ka'bah was burned" (Azraqī, *loc. cit.*, ed. Wüstenfeld, p. 153). A number of arguments may be cited in favor of the meteoritic origin. It is well known that even in the first decade of the nineteenth century, men of science were not sure of "stones falling from heaven." There can be no wonder that, for lack of adequate information about the nature and characteristics of meteorites, even geologists of those days went wrong in their "diagnoses" of the Black Stone.

It is significant that Thomas Carlyle, in "Hero as a Prophet," says: ". . . Diodorus Siculus mentions this Caabah [Ka'bah] in a way not to be mistaken, as the oldest, most honored temple in his time; this is [was] some half-century before our era. Silvestre de Sacy says there is some likelihood that *the Black Stone is an aërolite.* In that case, some man might see [have seen] it fall out of heaven! It stands now beside the Well Zemzem; the Caabah is built over both . . ."

Azraqī's statement that the Stone was originally a star of Paradise (*loc. cit.*, p. 10) suggests that it may have been *seen at some time to fall as a shooting-star.* In the present writer's opinion, many people would prefer to assume that the tradition about the Stone's having been brought by the Angel Gabriel and given to Abraham and Ishmael for setting in a wall of the Ka'bah, arose out of an attempt to explain its witnessed fall as an aërolite, which may have happened not long before the first recorded rebuilding of the Ka'bah.

Lt.-Col. W. Campbell Smith (now Keeper of Minerals in the British Museum) in his paper, "A New Meteorite from Suwāhib, Arabia" (*Min. Mag.*, for March, 1932, p. 47) writes: "The only other *meteorites* from Arabia are the famous 'Black Stone,' set in the wall of the Ka'bah at Mecca, of which the history

goes back beyond the seventh century; a meteoric [meteoritic] iron, of which two large masses were found in 1863 in the Wadi Bani Khāled in Nejed (Nejd); and a gray bronzite-chondrite, which fell in the spring of 1910 at Et Tlahi in the HedJaz."

W. F. Denning (Hutchinson's "Splendour of the Heavens," p. 438), under the heading of "Falling-Stars," says: "In the seventh century, a stone fell which was built in the northeast corner of the Kaaba [Ka'bah] at Mecca, and afterwards worshiped by the Moslems." It may be pointed out here that the fall did not occur in the seventh century, but, in all probability, much earlier, perhaps at the time of Abraham; and that, though the Stone may have been worshiped along with other idols of the Ka'bah by the Arabs before the advent of Islam, it has been, since then, only *kissed* by the pilgrims in their circuit of the Ka'bah. The statement in Professor H. H. Nininger's "Our Stone-Pelted Planet," on p. 226, concerning the date of the finding of the Mecca (Kaaba) Stone, as A.D. 1772, also needs correction. Philip K. Hitti of Princeton University, in his "History of the Arabs" (Macmillan, 1937, p. 100) writes of the Ka'bah as a building of primitive simplicity, originally roof-less, serving as a shelter for a *black meteorite*, which was venerated as a fetish.

In the bibliography of the Black Stone, mention may be made of a book in Arabic by Ibrahīm Rif'at Pasha, entitled, "Mir'at-al-Haramayn," 2 vols., pub. lished by Dār-ul-Kutub al Misriah, Cairo. The Stone is described in Vol. I, pp. 301-8. Two papers in Urdu, by Alī Shabbīr of Hyderabad, published in *Lis-ān-al-Mulk*, Vol. III, No. 2, pp. 69-88, and No. 4, pp. 189-222, October, 1924, based mostly on the foregoing authorities, are full of interesting historical and anecdotal details, on the subject of the Black Stone.

The present writer has much pleasure in expressing his indebtedness to Professor D. S. Margoliouth of Oxford, for references to the works of Azraqī and other Arab historians mentioned in this paper, which have been consulted wherever possible. References to Ibn-Taghrī Birdī have been kindly furnished by Professor Jamīl-al-Rahmān of the Osmania University.

1938 March 31.

The Meteorite which Penetrated a Roof at Baxter, Missouri*

By H. H. NININGER

The American Meteorite Laboratory, through the coöperation of Mr. Frank Clay Cross, recently received a very interesting report to the effect that a meteorite had crashed through a house-roof in Stone County, Missouri, near Point Lookout, in the year 1916. Naturally the report was doubted for the reason that many similar accounts which have been received in the past have proved to be either impossible of verification or definitely false. When the specimen arrived at our Laboratory it proved surprisingly to be a genuine aërolite whose state of preservation was almost perfect. There was nothing about the specimen that appeared in the lease inconsistent with the date of fall as reported. However, there still lingered a serious doubt as to whether such an event could have escaped the knowledge of the scientific world since 1916, the year in which the fall was said to have occurred. In order definitely to settle the question, a representative was dispatched to Point Lookout to investigate. It was not at all difficult to verify the

*The original announcement of this meteorite was made in a note entitled "The Baxter Meteorite," in *Science*, **87**, 234, 1938.

truth of the report. Mr. J. W. Jackson, who had been a witness to the impact, was interviewed, as was also Mrs. Frank Jackson, who was in the house at the time of its penetration by the meteorite. The event had been recorded in the local newspaper at the time and the date of fall was therein given as January 18, 1916. The following is copied literally from the *Stone County Oracle* for January 26, 1916:

FIGURE 1
THE BAXTER, STONE CO., MISSOURI, AËROLITE
(*Brustseite* view.)
(The scale is numbered in cm.)

"About 9 o'clock A.M. on Tuesday the 18th, the citizens here were shocked by a loud noise in the elements which seemed to begin right over us. Three loud

FIGURE 2
THE BAXTER, STONE CO., MISSOURI, AËROLITE
(The pencil points to the "nose" of the meteorite.)

reports in quick succession resembling blasts or several sticks of dynamite discharged. Then the noise changed to something like someone beating on a large boiler, and it traveled toward the north as it died away in the distance. Its duration was as much as a minute. Some say they heard it for fifteen minutes. It's

got us puzzled. Readers, tell us if you heard it. Someone tell us your opinion of what it was. Some folks here thought it an airship sailing over, and that it turned loose some dynamite. It was cloudy, but the clouds were thin. It was heard eight miles south and six miles north, that we know of, and they all tell the same story about the noise and direction. We will be glad to hear from others in regard to it."

A most significant report was given by neighbors forty rods to the southwest of the place where the stone struck. Three men who were working in the field said that they were "showered with gravel" while listening to the noise which attended the fall. This statement accords with the report received by the writer in connection with the Archie, Missouri, fall of 1932. It is another bit of evidence supporting a growing conviction that the showering of fine particles in connection with aërolite falls should be regarded as more important for invertigation than the large fragments which are collected.

The aërolite, which weighed 611 grams, was purchased for the Nininger collection. Casts were made and a small section was removed from a broken corner, for study. The specimen appears to be of the ordinary chondritic type with numerous bright metallic grains embedded in a rather compact greenish matrix. The fusion crust, which is almost complete over the entire stone, shows faintly an oriented arrangement of flow lines. There is a slight discoloration from oxides of iron, both inside and out, but in the main the crust and the interior appear to have retained their original color. This has been designated as the Baxter, Missouri, meteorite.

A Meteorite Survey [Abstract]*

By H. H. Nininger

Results of a survey, which is being conducted by the American Meteorite Laboratory, emphasize the importance of a quantitative study of meteorites. Early impressions as to the rate of meteoritic additions to the earth were based upon very inadequate information. The present plan is to continue this survey to a point where reliable estimates can be made. It is important that each college and university become a source of information regarding meteorites, particularly in respect to their identity and scientific value. Three maps are presented [not reproduced here] showing comparisons between previous meteorite discoveries and the results of the present survey.

*This paper will be published in full, probably in an early issue of the *Scientific Monthly*.

Shower of Bright Meteorites

U.A.I. Circular 713 contains an account of a remarkable shower of bright fireballs seen in southern Sweden on the evening of May 27, from $18^h\ 20^m$ to $20^h\ 12^m$ U.T. About $18^h\ 40^m$ two fireballs of etraordinary brightness, visible in full sunshine, appeared over Bornholm Island. Mr. Corlin, of Lund Observatory, requests observers of these or other fireballs to send reports to him. The general direction of flight was from west to east. (*British Astronomical Association Circular*, June 10, 1938.)

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Harvard's New Bureau of Variable Star Research: A long-felt desire on the part of Harvard astronomers—not to mention others—to put to still greater use the more than fifty-year-old collection of stellar photographs is now made possible through substantial financial support from the Milton Fund of Harvard University. This two-year grant, recently made to Dr. Shapley, Dr. C. Payne-Gaposchkin, and Dr. S. Gaposchkin, permits the establishment of an intensive photographic survey of all known brighter variables—those above the eleventh magnitude—in both northern and southern hemispheres of the sky.

The Harvard plate collection, now reaching nearly half a million, has been persistently piling up this much needed variable star information. With a corps of well-trained examiners and observers, this collection should reveal extensive data on periods, ranges, magnitudes, apsidal motions, colors and color variations, hitherto little known and unavailable to variable star astronomers.

Those in charge of the program have formulated a well laid-out plan for the most effective use of these data. They propose to study approximately two thousand stars, some already well known and others little known, and still others for which no information exists at the present time except that they have been declared to be variable.

Doubtless this research will reveal many new and interesting types of variables. Perhaps more stars of the SS Cygni type—to date none is known to exist in the far southern sky—may be detected, possibly still more of the R Coronae Borealis and Z Camelopardalis types. It may be that many of the so-called "irregulars" will be found to be normal stars and, on the other hand, some of the supposedly, but little observed, "regulars" may prove to have little-suspected idiosyncrasies.

And too, this photographic survey should work hand in hand with the visual programs which have been carried on in the past, mainly by amateur variable star observers, and provide considerable data for the study of differences between photographic and visual light curves, so long a moot question among astronomers. The survey will doubtless augment, rather than decrease, the need for additional visual observations.

It is expected that variable star astronomy will be greatly enriched when this work has been concluded. Our variable star catalogues will certainly be improved and many values of period, range, etc., will be more reliably deduced. Let us hope that this bureau accomplishes its full purpose, and even if a million or two observations are required, which is undoubtedly the case, the early attainment of the goal is greatly desired.

100 Important Variables: The Variable Star Commission of the International Astronomical Union has recommended in its report the adoption of a list of 100 variable stars upon which particular stress should be laid in the matter of observations. This list is intended to supersede the so-called Nijland Lists submitted at previous meetings of the Union which contained more than 500 stars.

With the efforts of variable star observers concentrated on a shorter list of the most important stars, it is felt that vastly more will be accomplished in securing much needed observational data. Many of the 100 variables are in Nijland's original list, and visual observations in particular are still required to establish their types of variation, period, range, etc.

Included in the new list are stars of U Geminorum, Z Camelopardalis, and R Coronae Borealis types, or suspected of belonging to these types, for which only co-operative observing can accomplish the desired results and settle disputed statements. Also there are to be found in the list stars of RV Tauri, Double-Period, and Nova-like types, with a few "irregulars" added for special reasons.

Some of these stars have been recently added to the AAVSO observing program and eventually, it is hoped, most of the others will find places in this same program.

Copies of the list of 100 Important Variables will no doubt soon be available for distribution to interested observers.

Red and Blue Light Curves of AR Persei: An interesting study of the light curve of the Cepheid variable AR Persei, both in red and blue light, has been made recently by Dr. S. Gaposchkin. It is found that the red curve presents considerably more breadth at maximum than does the blue curve, while the reverse is true at the minimum. The steepness of rise of the two curves does not differ greatly. The blue curve indicates a hump or "still-stand" just before the rise to maximum, a feature barely noticeable in the red curve. The range in blue light is 1.02 magnitudes, whereas the range in red light is only 0.75 magnitudes.

James S. Andrews: Word has just been received of the sudden death on July 10 of James S. Andrews of Rutherford, New Jersey, Official Astronomer at the Rockefeller Center Observation Roof, New York, and editor of the Monthly Star Finder, now in its second year of publication. Mr. Andrews was an occasional lecturer on astronomy and an active observing member of the AAVSO. He was elected last December to membership in the American Astronomical Society.

New Observers and Observations: Recent contributors to the AAVSO observing program are Messrs. Wm. Blitzstein, Philadelphia, Pennsylvania; T. H. Mason, Toronto, Canada; P. O. Parker, Ooltewah, Tennessee; J. O'Keefe, Harvard Observatory; and Mr. Ruhloff of Beloit College.

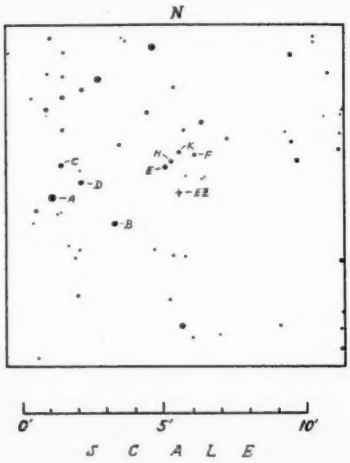
Name	May Var.	May Obs.	June Var.	June Obs.	Name	May Var.	May Obs.	June Var.	June Obs.
Ahnert	30	172	..	..	Diedrich	10	29	10	15
Albrecht	2	2	5	5	Ellis	13	17	11	13
Baldwin	91	205	74	130	Ensor	57	75	..	..
Bappu	..	..	33	145	Escalante	50	56	20	20
Blitzstein	..	..	5	9	Evans	23	42	..	..
Blunck	5	6	22	27	Fernald	11	41	17	62
Bouton	49	55	33	37	Focas	..	..	102	205
Brocchi	8	32	57	110	Forster	4	6	7	20
Buckstaff	7	10	10	14	Franklin	12	17	..	..
Callum	50	71	30	30	Gregory	28	30	140	220
Cameron	4	6	6	7	Halbach	15	18	4	4
Carpenter	112	184	32	32	Hartmann	152	247	97	190
Chartier	23	29	..	..	Herbig	131	445	88	140
Cousins	19	50	21	134	Hiett	33	66	19	39
Crout	7	10	..	..	Hildom	24	57	17	34
Dafter	6	10	9	34	Holly	..	..	3	3
Day	2	2	6	9	Holt	28	28	50	63

Name	May Var.	May Obs.	June Var.	June Obs.
Houghton	65	78	86	264
Houston	1	1	..	..
Howarth	18	22	18	28
Huffer	10	10	7	7
Irland	16	16	12	12
Jones, E. H.	106	462	75	245
Jones, M. D.	..	..	8	14
Kearons	29	60	35	59
Kelly	15	21	10	10
Keuziak	2	2	7	7
Kirkpatrick	47	218	42	172
de Kock	58	200	54	176
Kotsakis	..	..	48	59
Kozawa	..	..	7	30
Kretschmer	1	1	1	1
Lizarraga	..	..	6	7
Locke	5	5	8	8
Loreta	124	407	115	423
Mason	..	..	2	2
McLeod	22	56	20	22
McNabb	3	10	..	..
Meek	31	132	31	413
Millard	33	72	23	38
Monnig	..	..	2	3
O'Keefe	1	1	1	3
Parker	3	6	..	..
Peck	..	..	34	150
Peltier	190	240	188	233
Plueddemann	12	12	..	..
Prinslow	2	2	..	..
Purdy	6	12	8	21
Pursell	3	3	..	..
Rademacher	7	23	8	20
Recinsky	8	28	9	26
Rosebrugh	17	58	9	60
de Roy	12	69	13	57
Ruhloff	2	2	3	4
Russell	13	23	21	42
Ryder	11	11	9	9
Seely	5	15	9	22
Shafer	5	9	3	5
Shinkfield	12	12	11	17
Shultz	..	..	5	5
Sill	59	65	17	17
Smith, F. P.	26	36	23	43
Smith, F. W.	4	6	3	5
Topham	3	3	5	8
Treadwell	8	8	10	19
Vinson	1	1	1	1
Walton	7	23	..	..
Webb	22	22	13	15
Weber	22	23	10	10
Woods	20	68	18	38
Yamasaki	26	28	12	34

July 14, 1938.

EZ Aquilae

The variable star EZ Aquilae, position for 1900, R.A. $19^h\,34^m\,41^s$; Decl. $+8°\ 22'.7$, has been under close observation here for several years and has proved of exceptional interest. It resembles the RV Tauri type, but is probably regular, with two approximately equal maxima, two very unequal minima. Its period is



38.610 days, and from max_1 to min_1 is 17 days, from min_1 to max_2 6 days, from max_2 to min_2 12 days, from min_2 to max_1 6 days, approximately. The preliminary visual magnitudes of these four points are, respectively, 11.7, 14.1, 11.7 and 12.5?. It would be of the greatest assistance in the study of this star if we had information about its spectrum and also its color index changes, particularly as to the latter in the second half of its period. Even its class is unknown; this could be determined by one objective prism plate. This note is published in the hope that some observatory, with a very large reflector, will be willing to obtain these data for us. The star may well be an intermediate type and this justifies our request. A table of dates on which the star is above 12.1 magn. (visual) and of secondary minima is appended, as well as a chart for identification, the star being in the Milky Way.

I		II		III	
	M < 12.1 ±		Prin. Minima		Sec. Minima M < 12.5 ±
1938, Sept.	13-22	1938, Sept.	7-11	1938, Sept.	26-28
Oct.	1- 8	Oct.	16-19	Nov.	4- 6
	22-31	Nov.	23-27	1939, April	7- 9
Nov.	8-15	1939, March	19-23	May	16-18
	29-30	April	27-30		
1939, March	25-April 3				
April	12-19				
May	3-12				
	20-27				

Dates are inclusive.

CHARLES P. OLIVIER.

Flower Observatory, Upper Darby, Pennsylvania.

Comet Notes

By G. VAN BIESBROECK

No comets are under observation at this time. COMET 1938 *a* (GALE), the last one reported, is no longer in reach of northern observers. Assuming a period of 10.9929 years by comparison of the apparition in 1927 with this year's, L. E. Cunningham has deduced a new set of elements and a corrected ephemeris which will help the southern observers in following this faint object as long as possible. It moves slowly northward this month but by the time the region comes in our reach the light will be too feeble. The visibility will apparently not extend much beyond a couple of months.

The only other periodic comet expected at this time is SCHORR's found in 1918. But, since this object was followed for only 38 days after its discovery and has been missed at all following returns, the chances of the recovery of this faint comet are very slight.

This year's opposition of periodic COMET 1925 II (SCHWASSMANN-WACHMANN) has gone by unobserved. The writer has attempted to locate this comet many times in May and June but apparently it remained too faint to leave its impression on the photographic plate although stars as faint as 16th magnitude were recorded.

WILLIAMS BAY, WIS., JULY 26, 1938.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editors may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Light Behavior

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At the present time theories of light transmission are very much involved. The older textbooks speak in terms of light rays, transverse and longitudinal waves, while the recent ones discuss corpuscular transmission quanta and discrete darts. The existence of an aether is left unsettled.

Let us hope that time will develop one simple generalization of light mechanics that will eliminate all the present intricacies. Until that goal is reached any matter that is cogent and logical may have its day for consideration and possibly leave its trace on the final outcome.

In an earlier paper the writer has set forth that all light, whether radiant or reflected, in effect, travels from its center of generation in concentric spherical shells like expanding bubbles or balloons motivated from within. Choosing any star as an example, light from that star was believed to expand in true spherical shells to the farthest confines of our light universe. Every star in the heavens duplicates this action, filling the entire universe with radiations from all its contained stars.

Making a further selection of any random point in the heavens, light from every star in the universe is, barring occlusions, visible from that point, indicating that light shells from every star in light space come to and pass through that selected point.

All other smallest mathematical points in the universe receive light from all stars in like manner as the random point, thus indicating and confirming that light from every star in the universe, no matter what its manner of travel, passes continuously through every minutest point in the universe at every smallest interval of time.

By corollary, as one gazes at any star in the heavens, light coming from that star to the observer has intersected the light of every other star in the heavens at every smallest division of its advance, at every instant of time and from every possible direction of incidence.

All these intersections are made in the most perfect and imperceptible manner, without the misplacement of a single Fraunhofer line in the spectrum of any star and maintaining at all times absolutely straight lines of travel, unless for the exception noted by Dr. Einstein, who stated that rays from stars that should be temporarily out of sight from our earth, by the sun's occlusion, are deviated, as he explained, as they pass through the sun's gravitational field, so that they are observable during the total eclipse of the sun.

However, Major Albert W. Stevens in his recent stratosphere photographs taken during the Peruvian total eclipse has found trace of an outer enveloping "globular corona" surrounding the sun, which may make of this diversion of light a usual refraction phenomenon. It might also be noted that if the sun does attract light gravitationally, then light would be a gravitational body and light would

attract light. But light impulses have intermingled for hundreds of thousands of light years in their journeyings without diversion from the absolute straight line, so that light would seem to be a gravitational neutral.

The foregoing outline of the light intersection idea was possibly novel and interesting but a greater significance is derived from the bearing its further analysis may have when applied to current light theories.

As a first measure let us propose that light does, in effect, travel from its various sources in concentric spherical shells, expanding, with continuity, peripherally to preserve a continuous field, no blind spots, which also maintain their radii as straight lines to preserve a fixed field, also that the spectroscopic content of light from any unchanging source is unchanging. Through these expanding and interesting shells of energy our earth gyrates. Never twice does an observer encounter the same shell or, except in terrestrial observation, the same straight line radius.

Each individual star, then, may be considered the center of a vast globe of outwardly moving concentric spherical shells expanding radially at the constant rate of 186,324 miles per second.

It is known that each separate fused chemical element in a star's composition, all stars being closely alike, has its own fixed and entirely different set of Fraunhofer lines for its spectrometrical signature. Each separate line of any of these elements is maintained by its own definitely and equally spaced continuity of impulse shells. The impulse spacing for any line in one element is not duplicated by a line with the same spacing in any other element. Shells on different spacings which coincide is another problem which is as yet untouched.

There is an enormous catalogue of these Fraunhofer lines. Iron has about a thousand calculated lines, varying in impulse, peak to peak, from 2219.76 to 6678.27 hundred-millionths of a centimeter, or Angstrom. Intermixed with these in any star spectrum, with approximately the same range of peak distance, are the hundreds of lines of each of the other elements, each maintained by its separate and differing continuity of impulses of absolutely unchanging accuracy of time, spacing and speed. The single continuity of evenly spaced shells to generate one Fraunhofer line of whatever location and element in the total spectrum is the unit of the whole problem. Each of these continuities maintains its individual perfection as though it alone existed in all space. In the same medium its speed, length, and number of impulses are constant. Its position on the spectrometric scale unchanging except for cause.

A crude analogy of the total light from any one star may be had by considering a long conveyor belt of which we mark off a length of 186,324 miles, at such a distance of light year from the generating star that conditions have taken on their average fully merged state. Let this length of belt diagrammatically represent one second's travel of all the spherical shells generated by the star. It becomes the enlargement of an imaginary line radius of the combinations of spherical shells of all the stars' chemical content as they travel by us and is, of course, perpendicular to their surfaces.

On our chosen length of this conveyor belt are stretched lengthwise one wire for each Fraunhofer line in the entire combination of all the elements which are fused into that star's composition.

There may be four score elements fused in the star, each element generating a spectrum of an average of two hundred lines. One wire for each line aggregates about 16,000 wires. We will then suppose each wire notched evenly for its entire length with the exact impulse or wave-length of the one particular Fraunhofer

line for which that particular wire stands. The longest distance between notches on any wire being about 7000 hundred-millionths of a centimeter and the least distance approximating two-fifths of the above, so that all the wires will have at least one and possibly three notches on each wire in each 70 millionths of a centimeter. Each notch in each wire will represent the outer radius end of one spherical shell. Figuratively, consider the wires are clamped to the belt and the shells are clamped to the wires. All this amazing globe of concentric shells of which our belt length diagrammatically represents the first second's travel expands with no entry of one shell on another, no passing or jostling among the shells from a single source. Millions of shells for each centimeter of radius. Trillions for each second's travel.

Chaos would result if the light mechanism fell short of absolute perfection. We find no strays, everything definite, no conflict.

After contemplating the vast and orderly emanations, as above, of a single star, its product as perfect as though there were no others, visualize the fact that there are other stars, two billion or more other stars. Each generating a similar tructure of shells. These innumerable sets occupy each their place and travel oblivious of the existence of any other set. They flow through intersections showing no contact damage, so mathematically perfect that their intersections have never even attracted attention.

These phenomena, however, are not so remote in the depths of the heavens as to be beyond our notice. They are occurring in the space about us. We need not even reach out to touch them. Whether we are afield or within doors, every mathematical point generating or reflecting light is developing its series of spherical shells that make their orderly and invisible intersection all about us. Even within the very lenses of our eyes. The mode of accomplishment is a mystery of the Grand Architect, for one is constrained to believe it prearranged. Is there a more complicated, more awe inspiring, more perfect phenomenon anywhere in nature barring life itself?

In the study of a star's existence the most enlightening items are drawn from observation of changes either permanent or cyclical of its spectral lines. From the shifts of these lines, compared with a normal spectrum, can be determined the approach or recession of a star, the separation of an apparent single star into two or more components and the motion of these parts, the temperature variations, and star distances, and the vagaries of an expanding universe.

By the spectrometer at his hand the astrophysicist postulates the happenings of a million light years distance. The miraculous complications of the flawless road between has been overlooked.

The sun is our close-up star. Each point of it and its appendages is giving off its series of spherical shells. These shells gradually merge as they progress into space to and beyond the earth's distance, detail fading until albedo disappears and its light becomes the composite point observed from other suns, so distant as to be called stars. If the composition of the light surroundings of a sun do change at the beginning of its journey, as just noted, who shall say when the change is finished, or that the change is ever finished? It might be a matter of inquiry whether the great changes in the spectra of the farthest observed bodies may not be partially explained by their long and arduous travel as well as their connection with a universe that is still expanding.

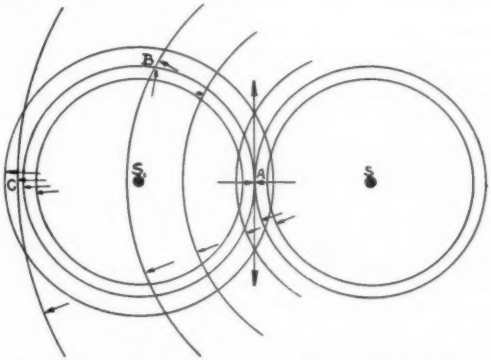
If the foregoing reasoning gives any color of reality to the filling of space with an everchanging grid of intersecting light impulses and energies the method of its activation becomes of interest.

The observer is only the recipient of light. The telescope is not an arm

whereby one reaches out and searches deeper and deeper among the stars. It is more like the baseball catcher's mit which handles only what comes to it. After the light has come to us we are allowed to analyze it. The 200-inch telescope will not reach two or four times farther into the celestial sphere. It will take the same light which has come to our 100-inch telescope and our eyes since Adam was in Eden and analyze it two or four times more minutely. The new galaxies it will uncover have always been sending us their light. The 200-inch instrument at Mt. Palomar will give us means to pick up and dissect that light just as there are possibly countless other galaxies awaiting more delicate resolution by greater or still more competent instruments.

On the same principle the soaring bird turns an acute eye and reads with great detail the light which always comes to his "high aerial lookout" whether he be there to read it or not.

There is no evolution in light. Whatever it is, it is as it was from the beginning. The light impulses that come to our telescopes, our microscopes, our cameras, our various structure of eyes are all the same. Each apparatus has its varying mode of translation. Light transmission then becomes as important a division of light study as generation or reception.



Intersections as at A occur on all Direct Radii,
Millions to the Centimeter,
Trillions each Second.

Does light travel as rays, discrete darts, or spherical shells? A ray of light, as it extends its travel, becomes a cone with no sharp limitations of the base which uniting with other rays bases merges into a constructive spherical shell. Discrete darts would follow the same idea, spreading into buttons which merge into a constructive spherical shell. Discrete darts would have neither radial nor surface continuity. They would be as flakes in a snow storm with no more chance of tracing back to an authentic point of origin than would a cosmic ray. However, it is arranged there must be some solidarity. Something to retain form, for the spherical shells are variously comminuted throughout their course but they do hang together perfectly and travel radially straight through air and space and lens.

In effect then, the spherical shell is a rationally possible mode of light travel although not as readily demonstrable as the intersections. It would seem that radial and peripheral continuity and coördination is necessarily assumed after consideration of the lack of blind spots in the various magnifications, attenuations, and

manipulations that light measurements, camera and laboratory usages have demonstrated. Nothing is supposed to travel faster than one way light. Yet in the intersections there would seem to be relative speeds developed beyond the dreams of relativity.

Light traveling from S_1 would pass the frame of light from S at A with a velocity twice that of light and the spherical shells at A would intersect each other on the tangent at a speed approximating the infinite varying through B at right angles to no motion at C between the shell series from S and the accompanying series from S_1. Almost identical and yet in practice sufficiently perfect to differentiate the double source.

Light impulses which are sufficiently robust to travel their thousands of light years and meet perfectly all the interactions of the intersections and the further stress of telescopic reception with its lenticular crowding and then be accurately spread out on the map of the spectroscope are the same light impulses which are so delicate as to lose without trace or turmoil any requisite portion of their constituent energies when they meet a surface or penetrate a transparency and give that surface or transparency without variation the color consonant to the texture found there or possibly lay down all impulse whatever on a black surface.

In the Wilson Condensation Chamber, X-rays, Cosmic Rays, and rays made by a manipulation of electricity only or of light and electricity in the photoelectric phenomena give distinct corpuscular or dart indications and tracks, but the retinal range light which allied with the above is used in the photography of the special effects without leaving any trace on the condensation so that it would seem of a different nature.

Shells and vector polarization will need some reconciliation, yet discrete darts cannot travel in the supposedly swaying motion allotted the polarized light convention and hope to get the perfect definition obtained in polarization work. Also polarized light seems to travel in spherical shells in all directions from a center.

420 West 24th Street, New York City. GEORGE N. COLE.

Notes from Amateurs

Amateur Astronomers of Tacoma.—The Tacoma Amateur Astronomers have an active organization as is indicated by the fact that they have issued a neat and convenient hand book for 1938. It contains lists of members and officers, a brief history of the organization, and the By-Laws. It evidently was financed through advertisements furnished by various business firms of Tacoma.

The Sixth Year of the Rhode Island "Skyscrapers"

The annual election and business meeting of Skyscrapers, Inc. (amateur astronomical society of Rhode Island), was held in Ladd Observatory, Brown University, on June 7, 1937. The following officers were elected: President, Frederick W. Hoffman; Vice Presidents, Donald S. Reed and Miss Victoria E. Atwell; Secretary-Treasurer, Miss Angeline M. Pettey.

The program of the sixth year was as follows:

1937 August 4. Outdoor meeting at the home of Mr. and Mrs. Frank P. Sherman, Johnston, R. I.

September 15. Outdoor meeting at Seagrave Memorial Observatory, North

Scituate, R. I., as a "welcome home" to Professor and Mrs. Charles H. Smiley. Professor Smiley gave an informal talk on his trip to Peru to photograph the total Solar Eclipse of June 8.

October 13. Professor Charles H. Smiley of Brown University lectured on his trip to Peru, under the title "8000 miles for 202 seconds."

November 1. Frederick W. Hoffman, President, gave an account of his trip to the West Coast in the summer of 1937, during which he visited several of the big observatories in this country and Canada, and most of the National Parks. He illustrated his lecture with movies and slides in color.

December 8. Mr. Harry A. MacKnight talked on the making of a Schmidt camera; Mr. Raymond Ball on the uses of hyper-sensitive films; and Mr. Donald S. Reed gave an account of his trip to Springfield, Vermont, to the Convention of Amateur Telescope Makers, and to Springfield, Massachusetts, to see the new Planetarium, the projection machine there being the first American made machine to be installed.

1938 January 5. Dr. Carl W. Miller, of Brown University, talked on "Infra-red Light and its Application to Astronomy."

January 31. Professor Leah B. Allen of Williams Observatory, Hood College, Frederick, Maryland, talked on "Aurorae and Zodiacal Light."

March 2. Mr. Lawrence H. Aller talked on "Planetary Atmosphere" and discussed the possibility of life on other planets.

April 4. Mr. John L. Euart read a fine paper on "Meteors"; Mr. Lewis J. Boss gave some of his reminiscences of Frank Evans Seagrave; and Miss Mary H. Quirk reviewed the life of George Ellery Hale.

April 29. Professor Charles H. Smiley of Brown University, Director of Ladd Observatory, was host to Skyscrapers, Inc., at the Observatory. Mrs. Helen Holmes read a paper on "Variable Stars."

May 27. The fifth annual dinner of the society was held at Faunce House, Brown University. Following the dinner over 200 members and guests of Skyscrapers, Inc., and members of the American Association of Variable Star Observers heard Dr. Carl L. Stearns of Van Vleck Observatory talk on "Comets."

During the winter we entertained several groups from schools, the Scouts, and from industrial plants, at our Seagrave Memorial Observatory in North Scituate, R. I., and the privilege of using our eight-inch refracting telescope was much appreciated. During the A.A.V.S.O. Convention at Brown University in May, we were host to the delegates at our Observatory, and Mr. and Mrs. Lewis J. Boss of North Scituate served tea at their home. One of the high spots in our winter program was our participation at Ladd Observatory in observing the Lunar Eclipse of May 14. About fifty of our members and students of Brown University gathered at 3 A.M. It was a fine night and we were able to get a great many photographs. At totality Professor and Mrs. Smiley served coffee and doughnuts, which were most welcome. We might mention here that we have built two fine fireplaces on the grounds of our Observatory in North Scituate, and it is our custom, during the summer, to cook our supper out of doors, before beginning our astronomical activities.

ANGELINE M. PETTEY, Secretary.

Star-Gazing at Riverview Park, Pittsburgh, Pa.

Popular illustrated talks on stars are being given at the Wissahickon Trailside Museum at 9 o'clock every Monday evening during July and August. The constellations illustrated during talks in the Museum will be pointed out under-the-skies after each meeting. We suggest you bring binoculars. The same star booklet used last year as a text, is being used this year. Leaders are members of the Amateur Astronomers Association. Star-gazing in 1937 was highly successful. This year the program is revamped, and will be even more instructive and more fun. You are cordially invited!

PROGRAM FOR AUGUST

August 1—"Constellations of the South," Virgo, Libra, Scorpio, Saggitarius, Capricornus. Leader, Warren A. Donaldson.

August 8—"Constellations Overhead," Boötes, Corona Borealis, Hercules, Ophiuchus, Serpens. Leader, Willard A. MacCalla.

August 15—"Constellations Overhead," Lyra, Aquila, Cygnus, Sagitta, Delphinus. Leader, Albert Will.

August 22—Review: Summer Constellations. Leader, Fred M. Garland.

August 29—Visit to the Allegheny Observatory.

General Notes

Dr. R. J. Trumpler of the Lick Observatory was appointed Professor of Astronomy in the Berkeley Astronomical Department of the University of California, upon the retirement of Professor A. O. Leuschner. Dr. R. T. Crawford was appointed chairman of the Department.

Dr. William Wallace Campbell, seventy-six, renowned astronomer and president emeritus of the University of California, his mind fogged by aphasia, and nearly blind, penned a note to his wife in which he wrote: "It is better that I go away with my powers nearly all gone," and then made his final expedition into the infinite on June 14, a suicide.

The Rittenhouse Astronomical Society of Philadelphia, and members of the Amateur Telescope Makers' Section of The Franklin Institute, upon invitation of Mr. G. H. Froebel, of the Westinghouse Electric and Manufacturing Company, visited the plant at Lester, Delaware County, Pa., on Saturday afternoon, July 9, to inspect the work on the 200-inch telescope mounting which is being constructed there.

American Astronomical Society

At the invitation of Professor Heber D. Curtis, the sixtieth meeting of the American Astronomical Society will be held at the University of Michigan, Ann Arbor, September 14-17, 1938.

Headquarters for the meeting will be the Michigan Union, which is on State Street, facing the university campus, about a mile from the railroad station. Three classes of accommodations will here be available: (1) rooms in the Union proper, each with twin beds and bath, single $2.50 per day up, double $4 to $6; (2) some rooms in men's dormitories attached to the Union, not suitable for ladies or families, $1.50 per day; (3) beds in a 12-bed dormitory with attached showers and lavatories, suitable for a group of bachelors desirous of refreshing memories of college days, $1 per day. Reservations should be made by addressing The Michigan Union, Ann Arbor, Michigan. Rates at the Allenel Hotel, on Huron Street facing the Courthouse, are essentially the same as at the Union, but this hotel is about a mile from headquarters and from the session room. All meals will be served cafeteria style in the large tap room in the Union basement, though some members may prefer to take their lunches in the cafeteria of the Michigan League, one block from the sessions. Abundant free parking is available in the rear of the Union. The men will probably prefer not to bring formal dress. Astrono-

mers of the equinox of 1950.0 may wish to bring bathing suits for use in the Huron River or Lake Angelus. Unusually interesting features have been planned for the concluding day.

At 8:00 A.M., on Saturday, September 17, in members' cars or by transportation to be provided, the Society will leave for Lake Angelus, 52 miles distant. Inspection of the McMath-Hulbert Observatory; motion pictures of recent solar prominences, etc. This will be followed by an al fresco lunch. For those who are not compelled to leave promptly at the close of the meeting, an excursion to Henry Ford's Greenfield Village will be arranged.

Observatory for Louisiana State University

Construction of a $5,000 observatory which will enable Louisiana State University to conduct astronomical studies on a par with its other research programs is now under way.

"With a new lens and the observatory in which to use it, the university will have one of the best college observatories in the South," Dr. David Vance Guthrie, head of the department of physics and astronomy, says.

"We are planning to expand the work in astronomy a great deal and to offer a popular, or nontechnical, course in this field, effective at the opening fo the 1938-1939 session."

The observatory will be located in a hemispherical domed room on top of Nicholson hall, physics and mathematics building on the university campus, and was included in the original plans for the building, one of the units of last session's building program. The Works Progress Administration is aiding in the construction of the observatory.

The dome, 20 feet in diameter, has a framework of steel. The walls are of wood and will have an outer covering of sheet copper. The walls of the circular room are of hollow tile and concrete as are the walls of the main structure.

The dome rests on a circular track which in turn is mounted on eight heavy rollers. The rollers are easily turned, according to Dr. Guthrie, enabling the dome to be revolved so that the shutter opening in the dome may be turned toward any part of the sky.

The telescope will be mounted on a concrete block in the center of the observatory, and the block will rest on thick lead plates which will absorb vibrations and enable a steadier view through the telescope.

The telescope will have a 10-inch lens, replacing the present instrument used by the department, which has only a four-inch refractor. The refractor will be delivered some time in the summer.

The Louisiana Observatory project is one of several of this type to which the WPA has extended its assistance. Some months ago, needed improvements providing storage quarters for equipment were made by WPA workers at the U.S. Naval Observatory plant in the District of Columbia.

Assistance also has been extended to universities and colleges throughout the country in the way of constructing or improving structures on their campuses. While such projects were undertaken primarily to provide employment for jobless able-bodied persons on the relief rolls, consideration also has been given to the point that the work they do be of some economic benefit. Among the 1,634 new educational buildings constructed with the aid of WPA labor are a considerable number sponsored by colleges and universities. This is also true in connection with the projects involving improvements to 16,421 already existing educational buildings.

POPULAR ASTRONOMY

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